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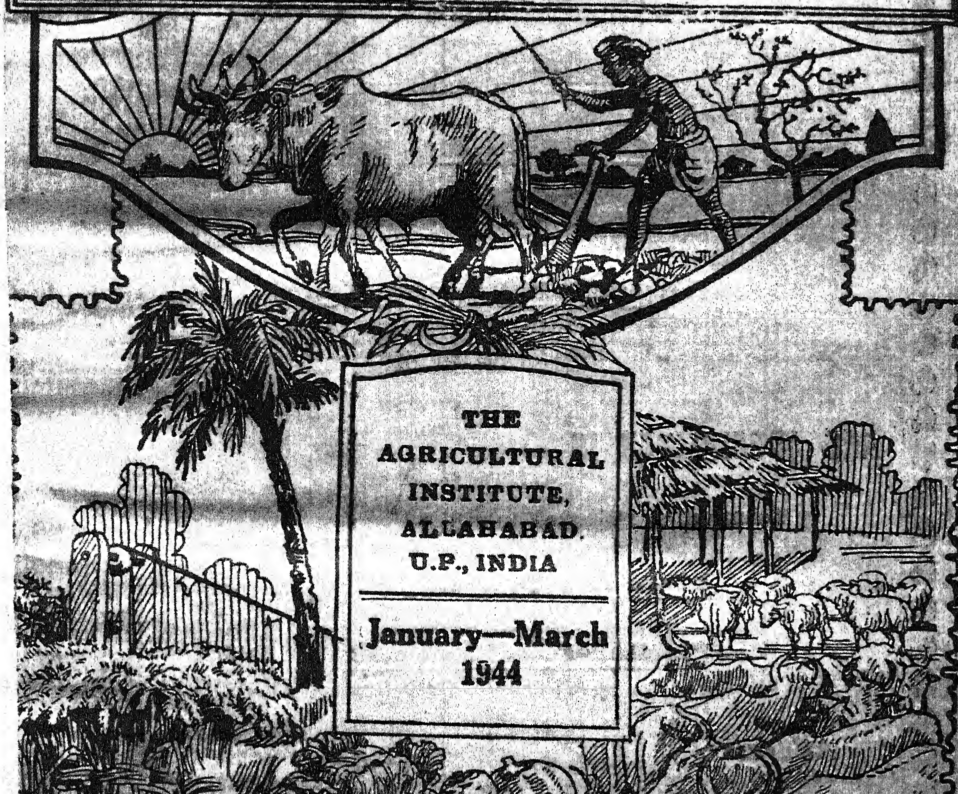
THE ALLAHABAD FARMER

A bi-monthly Journal
OF
Agriculture and Rural Life



THE
AGRICULTURAL
INSTITUTE,
ALLAHABAD.
U.P., INDIA

January—March
1944

The great disparity in the milk yields obtainable from Indian and foreign breeds lends weight to the evidence that germ plasm from the latter should be used to increase milk production in India. Unusual conditions demand unusual procedures, and there are more reasons for over-riding the prejudices against "cross-breeding" in India than in countries where the existing cattle have indicated greater potential milk-producing capacity.—*Professor Burch H. Schneider*—

THE ALLAHABAD FARMER

A BI-MONTHLY JOURNAL OF AGRICULTURE AND RURAL LIFE

The ALLAHABAD FARMER is now approved by the Directors of Public Instruction in the United Provinces, Bengal, Central Provinces, Sind, Assam, Bihar, and Orissa, the Rural Reconstruction Commissioner, Punjab, and by the Director of the Institute of Plant Industry, Indore, and Agricultural Adviser to Rajputana and Central India States, for use in all schools under their jurisdiction.

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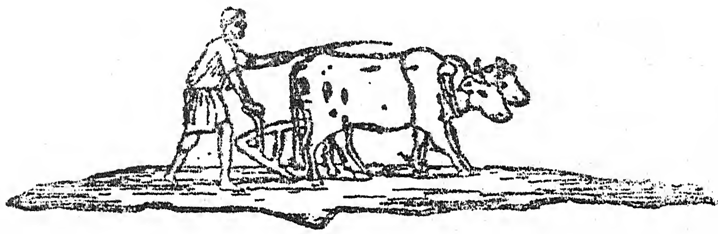

VOL. XVIII] JANUARY—MARCH, 1944 [No. 1-2

Editorials

This Issue a Special Animal Husbandry Number.

We take great pleasure in presenting to our readers the following articles on the subject of cattle improvement in this country. The article by Dr. Schneider who was for about five years the professor of Animal Husbandry in the Allahabad Agricultural Institute especially deserves mention. Although the article is very lengthy we have no hesitation in presenting it as one article, as breaking it up into two instalments, may not give our readers the full value that a single article would. However, we have decided to make this issue the January and the March issue combined. We hope that our readers will not have any objection to this decision of the Editorial committee of the Allahabad Farmer. We ask our readers, therefore, to take note that the January and the March issues of the Allahabad Farmer are being published this year as one volume.

Our Cattle population.

"According to the cattle census of 1935 and estimates for the uncovered areas, India possess approximately 230 million cattle and buffaloes or about a third of the world's recorded number......Although India has as many milch cattle as Europe including Russia, the production of milk is only a fifth of that of Europe"

—*Report on the Marketing of Milk in India and Burma*, 1941.

BREEDING FOR MILK PRODUCTION IN INDIA

BY

BURCH H. SCHNEIDER, PH. D.

Formerly Professor of Animal Husbandry and Dairying, Allahabad Agricultural Institute.

Milk is an important part of the diet of every great race of people. Milk more than any other single food meets the nutritional needs of the human body. It supplies almost all of the dietary essentials of life (all except iron, copper, and manganese). The proteins of milk are of the highest quality, possibly exceeded by egg proteins, and are a large proportion (about one-third) of the solids of milk. No common food is a better source of calcium, which is so important in building strong bones. Other minerals also are supplied by milk. Phosphorus is important and is furnished by milk in adequate amounts, although it is not as likely as calcium to be deficient in other human foods. Further, lactose, the carbohydrate of milk favours the assimilation of calcium. Other advantages also accrue to milk from lactose because this carbohydrate is not absorbed from the digestive tract as rapidly as some other sugars.

The fats of milk are very palatable as well as being readily digested and have small but apparently sufficient amounts of the essential fatty acids, linoleic and linolenic.

Milk is a good source of several vitamins. Vitamin A is contained in butter-fat in large amounts, if the cow is fed on green feed. Thiamin (vitamin B_1), a very important vitamin, is supplied by milk. Ascorbic acid (vitamin C) is present in fresh milk but is destroyed after standing or on heating. It supplies a small amount of nicotinic acid, possibly enough to prevent pellagra. Riboflavin is found in milk, and all of man's requirements for this vitamin can be obtained from milk. Vitamin D is also present in milk in small amounts.

Two-thirds of India's three hundred and eighty millions adhere to religious faiths which prohibit the consumption of meat, eggs, or any other food which requires the taking of animal life.* Milk is the only food of animal origin of which these millions of people can partake without violating their religious tenets.

All foods of animal origin have to some extent the desirable qualities which have already been described for milk. Proteins of animal origin are generally conceded to be superior to those of plant origin. Animal foods are excellent sources of calcium and phosphorus, vitamins, etc. Foods of animal origin are a vital part of the dietary of every pro-

* Certain Hindu castes do eat some fish and meat of certain species, and individuals of all castes eat eggs, meat and fish, but this does not invalidate the general applicability of the above statements.

gressive people. Dairy products are greatly appreciated by the people of India, and if available at prices within their purchasing power, would be consumed in much larger amounts. If milk is the only food of animal source permitted by the religious faiths which claim the largest numbers of India's population, it is of greatest moment that we consider India's milk consumption and the possibility of increasing the supply.

Wright ('37) points out that India stands lowest in a list of twenty great countries with an average daily consumption of milk and other dairy products of 7 ounces of milk equivalent per head of population. In certain cities the average consumption of fluid milk is as low as ½ ounce per person daily. The average per capita consumption of milk equivalent in seven cattle rearing areas was 10·16 ounces daily (Olver '37). But even in these areas where milk might be thought to be cheapest and most abundant, 46 per cent. of the population (including children at the same percentage) consumed no milk.

McCarrison ('32) has convincingly demonstrated the adverse effect of various Indian diets on health and vigour. No authority on human nutrition would deny that to increase milk consumption would add more to Indian diets than any other single food which might be suggested to the vegetarian population of the country.

" Crossbreeding "

In a country where the disparity between the milk production of the native and foreign cattle is as great as in India, and where there is so great a need of milk, the problem of introduction of foreign cattle is certain to be brought forward again and again.

In India, the word "crossbreeding" has come to have the meaning of "breeding any animal which has any indication of having foreign characters". Any animal showing the slightest indication of the presence of foreign breed characters is called a "crossbreed". "Crossbreeding" is actually the mating of animals, one of which is of one breed, and the other of another breed. The offspring of such a mating may be called a "crossbred", even though the parents represent two Indian breeds Any further matings of these crossbred animals do not produce crossbreds. The first cross only is by definition a crossbred. Thereafter, a system of breeding other than crossbreeding must be followed, unless we should introduce a third breed.

All breeds of cattle have some genes which are less desirable than other genes. Most undesirable genes are recessives. The importance of this in crossbreeding is that the characters from undesirable genes are usually covered up by corresponding dominant genes of the other breed. Seldom do two breeds have the same undesirable characters. This blend of desirable dominant characters from two breeds causes what is known as "hybrid vigour" in the first generation. Such

animals usually are more thrifty than either parent; they grow more rapidly, fatten on less food, and produce more milk than would be expected from their pedigrees.

Crossbreeding is often of value because of "hybrid vigour" and also is valuable as a means of introducing desirable characters into a breed in which they have not existed formerly. There are those who state that they propose to improve Indian dairy cattle entirely by selection They may succeed. They may not. Success is relative, not absolute. How high a milk yield is desired? If Indian cattle do not have the genes for high milk production, it is not possible to select cows having them.

Potential Milk Yields of Indian Dairy Breeds

A fundamental question is: "Can Indian cattle be improved to be equal to Western cattle by selection only?" We may reply by asking another question, "Do Indian cattle have in them the genes for high milk production?" There are those (Olver '34) who compare the highest producing indigenous cows with the average of all cows in the United States. The average of all cows, good and bad, beef cows and scrub cows, as well as dairy cows, in the United States (Milk Facts '40) and in the United Kingdom (Wright '37) is about 5,000 lb. per year. If we are to compare this figure with anything in India, we must compare it with the average of all cows in India. Wright ('37) estimates this at 600 pounds of milk per cow for a year for the entire country while Olver ('37) found the average production to be 943 pounds per lactation in seven cattle breeding areas of India. One or two of the best herds of Indian dairy cattle have averaged about 5,500 pounds of milk annually per cow,* with milking not more than three times daily. The author has not been able to find a herd of Indian cattle with "an over-all yearly average of 8,000 lb. of milk with a butter-fat content of over 4·7 per cent.," as stated by Olver ('33).

If we desire to compare maximum productions, there are a few Indian cows which have produced over 11,000 lb. of milk in lactations of normal length.† The production of over 11,000 lb. of milk per lactation in Indian cattle has been obtained by milking four times daily, and all the conditions of feeding succulent fodders and plenty of concentrates used to produce the maximum yield of over 30,000 lb. cf milk in the maximum productions of western cattle.‡ The only condition of envi-

*The Government Military Dairy Farm, Ferozepur. (Private study by the author). The Imperial Agricultural Research Institute, New Delhi.

†The cows, Laruli No. 604, 11,003 lbs. in 10 months, and Chansuri No. 653, 10,119 lbs. in 10 months, at the Imperial Agricultural Research Institute.

‡The cow Carnation Ormsby Butter King produced 38606·6 lbs. of milk in 365 days under official advanced registry supervision. Johanna Hester Prilly produced 41,414 lbs. of milk in a Dairy Herd Improvement Association. Cherry, a grade Milking Shorthorn cow, has been claimed to have produced 41,644½ lbs. (The two latter records were not as closely officially supervised as the former.)

ronment at New Delhi or Ferozepur which is less favourable than that of cows making the highest records in western countries is that of high mid-summer temperatures. Indian temperatures are sometimes rivaled in summer in North America, where also the low mid-winter temperatures with the consequent confinement in barns with stored food (not stimulating fresh green roughage) may be less favourable.

Watkins ('35) writes, "... .. selection can do no more than isolate the best combination of existing factors, though we cannot tell beforehand how much better that best will be." From previous observations of selection at work, it appears that the most rapid advance is made when selection is first applied to a certain character. The leading herds of improved Indian cattle in India have all been established for 25 to 50 years. Improvement has been brought about by selection, but continued improvement at the same rate cannot be assumed. If selection makes the most rapid progress at first, then it becomes slower as undesired genes become fewer and the desired characters increase, (Lush '37). Cows of the Sahiwal breed had produced 7,000 lbs. of milk per lactation 25 years ago (Henderson '17), (Shearer '09). Cows of western breeds had produced over 30,000 lbs. of milk 50 years ago (Graves and Fohrman '36), (Prentice '35). Sayer ('34) found that none of the cows at Pusa was producing over 7,000 lbs. per lactation in 1932, 26 years after the establishment of the herd. The highest records of Western cattle are still of the order of 30,000 to 40,000 lbs. In neither India nor in the United States had very much "scientific" breeding been introduced 25 to 50 years ago, respectively. It is doubtful if Western or Indian breeds of cattle can be improved in the future at as rapid a rate as when selection first began. The evidence from records of production is that both are on a latter portion of the curve of selection. Indian cattle are far behind the European breeds in milk production, and present curves indicate that they will never catch up.

Men who advocate "crossbreeding" are criticised as being hasty and lacking patience, desiring "short-cut" methods and not having the thorough-going spirit of painstaking research shown by the men undertaking the long-time process of cattle breeding by selection. If we were certain that selection would accomplish the task we might confine our efforts to this alone. Research endeavours to check all possible ways of accomplishing the goal Selection alone may be slow. It may be *never*! Never, if we are aiming at milk yields that compare with those of Western breeds of cattle.

The daily over-all herd averages usually published by Government farms in India (Wright '37) show excellent work in culling poor cattle from the respective herds, but they do not demonstrate that better cattle are being bred. Cows producing over 7,000 lbs of milk per lactation were in these herds 25 years ago. Sayer ('34) states that milking four times daily and improved feeding practices increased the

production by 47 per cent. It would appear, therefore that increased production is due to these factors, not to having bred better animals. The better producers of the 7,000 to 8,000 lbs. class have been multiplied and made more numerous, but they have not been made better by breeding. Higher production is a triumph of skill in feeding and management, not of breeding Selection is not producing a better Indian cow than we had 25 years ago. Selection, no matter how skillfully done, cannot produce cows capable of yielding more milk than they have inherited genes enabling them to yield. It has not been proved from records of production that Indian cattle have the genes necessary for high milk production. At least this is not sufficiently certain that it should be the exclusive method of trying to increase the supply to meet the country's need for milk.

The statement of Kay ('33) that "the law of diminishing returns begins to operate at about 700—800 gal. in that for every gallon of milk produced beyond this figure, the quantity of concentrates required by the *average* animal increases steeply, and influences more and more seriously the net cost of production of the extra gallonage", has been accepted too literally. (Italics added). The breeding of the cow determines the point at which the law of diminishing returns begins to operate. The key word to the quotation is "average." The point at which the law of diminishing returns begins in *average* cows in England may be 700—800 gallons A great deal of milk in England is produced by dual purpose cows, bred partly for beef. Their point of highest efficiency is certainly lower than where the bulk of the milk is produced by more specialized dairy cows. It may be much lower in Indian cows. Morrison ('36) states: "Even good dairy cows require for more maintenance of their bodies about one half the total food they consume. Only the remainder can be used for milk production." We need to have more efficient cows which produce more milk. For an equivalent tonnage of food we want to produce more milk and maintain fewer cows' bodies. This can only be obtained by breeding higher producing cows. We cannot accept the statement of Kay as an excuse to be content with mediocre cows. Wright ('37) also agrees that increased milk yield is essential for economic production.

There is little need of introducing foreign breeds of cattle into India for any purpose other than for milk. Some of the finest specimens of draft cattle in the world may be found in India. No one who knows India would suggest introducing Western beef breeds on any large scale. By far the greatest justification for introducing any Western blood into Indian cattle is for milk.

The Introduction of Foreign Dairy Bulls

It is widely stated that "crossbreeding" in India has failed, this, in spite of the phenomenal success of the Government Military Dairy

Farms in using bulls of foreign breeds. Nevertheless, the farms maintained by the agricultural and veterinary departments of the Government of India and the provinces have largely discontinued the introduction and use of bulls of foreign breeds. Most government farms have entirely dispersed their "crossbred" stock. It appears also that it is the intention to keep whatever good is obtained from foreign cattle on the Government Military Dairy Farms securely "bottled up" on those farms so that the rest of the country may obtain no benefit from it.

Henderson ('27) deplored that, "Frequently the opponents of this policy have condemned it without any knowledge of the results already attained by cross-breeding. There are reliable data available which, if collected and analysed, would form a basis for discussion as to the success or failure of this policy." Nevertheless, in spite of this plea for fair consideration, crossbreeding was discontinued like a half-uttered sentence. This means of increasing milk production manyfold in a land of great milk scarcity was dropped without preserving any of the valuable breeding stock or data acquired.

The Royal Commission on Agriculture listened to the testimony of many livestock experts, and made the following recommendation.

"Any commercial dairy farms that may in future be set up for supplying milk to cities would be likely to resort to crossbreeding with the object of securing first-cross heavy milking cows, and they would benefit by the very useful work being done on the military dairy farms in testing the merits, for Indian use, of different breeds of imported bulls. Meanwhile, we do not think it desirable that the agricultural departments should experiment in this direction. If they are under contract to deliver milk from their farms, there is no objection to their breeding first crosses for commercial purposes ; but their cattle-breeding endeavours should centre round the improvement of the milking qualities of indigenous breeds like the Sahiwal and Sindhi which are already noted for their milking properties, or on specially selected strains of other breeds like the Hariana. The work recently begun at Hissar suggests that, by selection for milk, it would be possible to evolve some fine strains of dairy cattle from this breed. If the adulteration of milk can be effectively dealt with and the time is reached when the supply of milk to cities becomes a business in which honest men can compete with prospects of success, the existing keen demand for good cows will be intensified ; and much useful work lies before livestock experts in developing the milking qualities of these valuable breeds of cattle." (Royal Commission of Agriculture, '28).

It would seem that the object of all Government cattle breeding farms should be to produce cattle capable of meeting commercial demands. As long as it is recognised that "crossbred" cattle are the only animals capable of meeting a year round commercial market, they should not be ignored in an experimental breeding programme which

seeks to meet the needs of the nation. The difficulty of the problem should not be a deterrent where such marked differences in production are observed in a land having millions of low-producing cows and a shortage of milk. There should be room for more than one experimental approach to the problem. Foreign "blood" need not be introduced to "make a new breed," but to improve an old one. The factors for milk production in Western cattle can contribute to the germ plasm of the already established breeds of cattle in India.

Successes of "Crossbreeding"

A great deal has been written and said about breeding for milk production in the tropics. Hammond ('31), Edwards ('32), Cousins ('33), and Lecky ('34-'35) have studied the crosses of Indian and Western cattle in the British West Indies, where such breeding has been carried on successfully. Kelley ('32) made a survey of "Zebu (Brahman) cross cattle" in various parts of the world, and advised their introduction into Australia. Lush ('33) reports favourably on the use of Indian cattle to develop a more satisfactory animal than pure European breeds in Texas. Rhoad ('38) recommends the crossing of *Bos taurus* and *Bos indicus* to meet South American conditions. Menresa ('37) is opposed to the introduction of Western breeds as such into the Philippine Islands, but endorses the "blending of the desirable characteristics of the Western breeds with those which can live in the tropics" ('39). It is interesting that he advises that this work be done on Government farms rather than by private breeders, the opposite of the suggestion given by the Royal Commission on Agriculture in India. Sikka ('31) cites data which show "the extremely poor milking qualities of Indian cows and the highly efficient nature of cross-breds as milk producers." Kartha ('34) made a statistical study of the economy of milk production on the Government Military Dairy Farms and rated "Crossbred" cows, buffaloes, and Indian cows, respectively, in order of their economic production of milk. Olver ('38) fails to point out any fallacies in Kartha's data or conclusions.

Reason for the Alleged Failures of "Crossbreeding"

There are at least three explanations which might be given for the so-called failures of "crossbreeding" experiments in India. The first is the conclusion most commonly given. The second and third possibilities are suggested by the author as alternate explanations.

1. The introduction of foreign cattle into India is fundamentally and inherently wrong.

2. The individual bulls which have been imported have not been the best representatives of their respective breeds.

3. The method of introducing foreign blood into India has not been the best, and it is the method used thus far which has failed.

Is "Crossbreeding" *Per Se* Fundamentally Wrong?

The first reason given for the so-called failure of "crossbreeding' is the only one ever mentioned by those who are opposed to the introduction of foreign cattle. It is said that "crossbreeding has failed", but no question is asked, "why has it failed?" Of course, there are difficulties to overcome. One should not condemn all introduction of foreign cattle simply because some bad results have been observed. Prentice ('35) shocked breeders of the old school by intimating that there might be improvement of the dairy cattle in the United States by crossbreeding certain of the established Western dairy breeds. He suggested that milk production might be increased by mating individuals, irrespective of breed, if they have high producing offspring. However, valuable this practice might appear to be in America, there is more reason for such a suggestion in India, and less reason to oppose it. This is because of the great disparity between the milk production of foreign and Indian breeds, the total inadequacy of the present supply of milk, and the lack of any organization of breeders to insist upon a traditional breed type. If a breed does not have all of the genes necessary for the highest production, we know of only two ways whereby those genes may come into the germ plasm of that breed:

1. By mutation.

2. By introducing the desired genes by an outcross to another breed which has them.

Mutations do not have a very large place in the breeding programme of the cattle breeder. He has no control over them. An increase in the number of mutations has been caused in some species (not in cattle) by special means such as X-rays, radium, etc., but no one has ever controlled the nature and kind of mutation. Most mutations are undesirable. Not one gene in a million gives a desirable mutation. If a cattle breeder could increase the number of mutations in the hope that valuable genes for high milk production be obtained, the net result of such a process would be a greater number of bad genes than good ones. The cattle would be made worse, not better.

If the Indian breeds do not have the genes for high milk production, and there is reason (as stated in previous paragraphs) to doubt that they have, we know only one way to introduce the genes for higher production. That way is to introduce them from another breed which has them. A European breed may introduce genes for high milk production, but also introduce other genes which are not desirable in an Indian environment. These undesirable genes are those which make the animal less suited for survival in the Indian climate, and cattle having too many such undesirable genes are certain to be eliminated by natural selection, if not by man. Nature is relentless. The net result to India will be beneficial, as the background of Hindu culture prevents the elimination of cattle merely because they are

unproductive. Nature does not know any religious inhibitions; "survival of the fittest" has full sway. By a system of crossbreeding, high milk production is introduced by breeding, but nature does the culling, if necessary, without asking of any man that he violate his religious scruples or those of his neighbours.

Wright ('37) states, "Complaints have indeed been made in the past that the sale of cross-bred animals from such (Government Military Dairy) farms has led to deterioration in the quality of local stock." On the other hand, MacGucken ('37) shows that any percentage of foreign breeding improves milk yield. This, also, is the testimony of many city gwalas (native dairymen) maintaining successfully all shades of mongrel cattle. The author has never seen an animal having evidences of foreign breeding so poor, but that he has seen pure Indian cattle just as bad. He has listened to "livestock experts" bemoaning the harm done by crossbred bulls, but he has never been informed specifically just what harm had been traced clearly to the foreign breeding. There are no data published which show that the poor types sometimes encountered among European—Indian cattle are any worse than the same Indian cattle might have been if no European breeding had been introduced. And the fact remains that the worst of these non-descript cattle, the results of the worst of methods of breeding following the first cross, still tend to produce more milk than other cows of the same female line which have no foreign blood.

Carruth ('21) writes that in Madras, in spite of the very unsystematic breeding, bulls often serving their own progeny for one or two generations, cows showing the "slightest trace of what is termed 'foreign blood'" are called "crossbreds" and are much more highly valued by the dairymen than the native breeds, and few are inclined to part with this class of stock. It is found not only do they give more milk per day, but also that the lactation period is longer; they also calve at an earlier age and breed more regularly.

"The great care with which the heifer calves are reared when compared with those in native breeds, shows without doubt how much such animals are in favour. Again, dairymen say that it is better to pay Rs 5 for the service of a cross-bred bull than Re. 1 for, say, a pure Ongole. A few of the bulls from the better cross-bred cows are fairly well reared in the hope of being sold or used as a seed bull, but excepting these, bull calves are rather badly reared, and looked on rather as part of the means for getting the milk from the cow. The heifer calves are reared with a view to bringing them into the herd later on.

"Generally speaking, the dairymen have got a got a fairly good grasp of the proper treatment of this cross-bred class of stock. They say that cross-breds are not so hardy as the native cattle, and, therefore,

require more care and better feeding, especially in the rearing, more protection from the sun, more general attention, etc.

This statement of Carruth corresponds with the observations of the author among the gwalas of North India.

European cattle were introduced into the district near Patna more than 50 years ago. The village breeders have selected for the hump-less character. These cows are greatly prized and known to be superior in milk production. As testified by Henderson ('27) before the Royal Commission on Agriculture in India, it is doubtful if an equal improvement could have been made by the introduction of a better breed of indigenous cattle into that area. This mixture of European and village now commonly known as the "Taylor Breed", "gave a much larger yield of milk and so it held its place."

If these cattle of foreign breeding have found a place in the country, and have helped to develop an improved dairy type without the guidance of anyone trained in the science of animal genetics, it might be expected that men trained in this field could develop something better. The Royal Commission would set the forces of variation resulting from crossbreeding loose in the hands of commercial dairy farms, but "do not think it desirable that the agricultural departments should experiment in this direction," even though provincial livestock experts "have been faced everywhere with an insistent demand for more milk production."

The method of introducing foreign "blood" is important, and if properly done, it remains to be proven that crossbreeding would not be the means of beginning the development of a high-producing strain of cattle adaptable to India.

The Importance of the Individual Bull

Matson ('28) and MacGuckin ('37) both warn regarding the type of bulls to import into India, but much has been said and written about crossbreeding in India which reveals that many others accept all bulls of a breed as one entity. Henderson ('27) also states that "great care should be exercised in the selection of the foreign bull. Many unsuitable animals have been brought into India in the past." Watson's ('30) warning against the "everlasting problem of the 'Pedigree scrub'" should be observed in importing purebred Western bulls into India as well as in purchasing them for use in herds in Western countries. Breeders in the Western countries, from which bulls are imported, know that animals of any breed vary considerably in quality. They may vary not only in their ability to transmit high milk yield but also in their ability to withstand tropical climates. When asked which breed is the best, the stock answer of any professor of animal husbandry in Western countries is, "Individuals within a breed differ much more than breeds."

A Brown Swiss bull and a Jersey bull imported into India in 1924 continued in active service at the Allahabad Agricultural Institute until 1938 and 1940, respectively. These bulls demonstrated more than the usual resistance to Indian climatic conditions and showed much greater adaptability than other bulls imported by the same institution.

MacGuckin ('37), who presents data demonstrating the high value of Friesian cattle for "crossbreeding and grading" in India, nevertheless reveals that these results were obtained with imported cattle having lactation yields averaging 9,400 pounds. There has been no demonstration of Sahiwal bulls with 9,000 pound pedigrees producing a change equal to that found in records reported by MacGuckin by grading in any district in India. A purebred Holstein-Friesian cow at Agra produced 19,563 lb of milk in 365 days under Indian plains conditions*. A cross bred Friesian-Sindhi cow at Mhow even produced this amount of milk in 300 days†. At Bangalore an Ayrshire-Hariana crossbred cow, "Jill", had 18 calves during her lifetime and yielded 154,779 lb. of milk.

The author has never seen the pedigree of any bull in a published report of a cross-breeding experiment in India, and it would appear that a sire index was entirely unthought of to give the reader an idea of the quality of foreign breeding which "failed" in crossing with Indian cattle. Breeders in South Africa, Australia and America have paid thousands of guineas for bulls in England. There have been no such sums spent for bulls to be exported to India. MacGuckin ('37). quotes Rs. 1,000 to Rs. 1,500 landed in India as the price to pay The greater risk in taking bulls into India is, undoubtedly, a deterrent to paying as much as buyers from other countries. However, the fact remains that breeders in England and in other Western countries are not going to sell their best bulls to India unless they are well paid for them. The quality of the bulls introduced into India is certainly on the average far below the quality of the bulls imported by other countries to improve their stock.

The Method of Introduction of Foreign Cattle and the Alleged Failures

Anything may fail if it is not properly carried out. A wrong method of doing any good thing may bring criticism. Few people deny the superior qualities of the crossbred cow. Marriot ('27) testified, "With the half bred we can count on 99 per centum being economical animals, and so we have rested content with that." Others have not "rested content with that." It is impossible to stop there, for dairy

* Carnation Gorben Segis, No. 1326324, owned by R. E. I. Dairy, Dayalbagh, Agra.

† Parbatti, crossbred Friesian-Sindhi, produced 19536·5 lb. of milk in 300 days at the Government Military Dairy Farm, Mhow.

cows must produce offspring to produce milk. The problem has been what to breed the crossbred cow to. It is impossible to separate on a commercial scale the functions of milk production and reproduction. The author has talked with several managers of dairy farms in India who revealed that they had been trained to revere pure breeding. There is reason for these attitudes in countries where there are already well-established breeds, breed societies with fixed rules and standards, and breeds of relatively high production. Pure breeding is worth preserving if it is useful. There is no need of breeding pure for mediocrity.

Dairy farms which have commercial requirements to meet frequently have great difficulty in doing so with Indian cows. Livestock experts in the provinces sometimes have gone beyond the recommendations of the Royal Commission on Agriculture and "warned" such men not to take up crossbreeding. Such dairy farms frequently have annual budgets for replacement of cattle (which is entirely unnecessary in self-propagating herds of Western cattle) but still cannot meet market requirements at certain times of the year Managers of such farms, even when committed to the policy of breeding only "pure" Indian cattle, take sidelong glances at crossbred cattle. One such manager expressed the wish that he might have "just a few" cattle with foreign breeding to supply his market and hold his business during the season of the year when practically all Indian cows were dry. When asked what he would do with the calves of such crossbred cows, he confessed that he had no plan except to discard them. He was thoroughly committed to the idea that such calves should not be reared.

A cattle breeding committee appointed by the Bombay Government reported in 1923, "—a number of enterprising people have started dairies but all, almost without exception, have failed, firstly, owing to the poor milk-producing qualities of the cattle; secondly, for want of protection by legislature; and thirdly, for want of encouragement by Government." (Marriot '27). The only non-political and scientific reason given for the large number of failures of commercial dairies was "poor milk-producing qualities of the cattle."

Several of the largest commercial dairy farms follow a policy of continued crossbreeding. They must purchase a new bull from abroad every few years. From time to time they purchase some of the best Indian cows that may be obtained in the cattle breeding districts. These are bred to foreign bulls. The crossbred cows are milked, and their three-quarter-bred female calves usually reared. The next generation, however, is almost invariably discarded. Experience has shown that it does not pay to rear calves under commercial conditions which are more than three-quarters foreign breeding This is a very expensive and wasteful method of breeding It is costly to the individual dairy farm (although more economical than maintaining a herd of pure Indian cattle) and wasteful of the country's resources. This system

just as effectively stops the best bloodlines of cattle, as breeding outstanding mares to produce mules would stop family lines in horses. Marriott ('27) admitted the truth of this statement to the Royal Commission on Agriculture, but denied that the Government Military Dairy Farms were serious offenders. There are, however, many dairy companies which continually buy livestock from the better breeding areas. A number of contractors make very good incomes by continuing to supply these cattle to urban dairy companies. These commercial farms receive high prices for their dairy products They believe that they can afford to use wasteful methods of breeding. They have the money to buy some of the best Indian stock year after year, but their system of breeding eventually causes the cessation of some of the best germ plasm in Indian cattle, which should be preserved in any successful breeding system.

The Government Military Dairy Farms (MacGuckin '38) have suggested "backward and forward" crossing, that is, first breeding to European, then to Indian bulls, a policy of continued alternating breeding. This plan has not been pursued extensively, however. Winters, Jordon, and Kiser ('34) advocate a system of breeding similar to this to obtain hybrid vigour in swine, but the situation in swine is not comparable. Such a system of breeding with dairy cattle leads to nothing permanent, genetically. It establishes no permanent germ plasm. It is at best only a commercial expedient. Someone must breed good purebred bulls to use in this system. India needs breeders who are breeding toward a goal. This system does not establish stock tending to become more prepotent and "true breeding". In countries where good bulls are always available from other breeders following other systems (which is not true in India) this system might satisfy some commercial dairymen.

One thing is certain: Commercial farms in India are going to continue "cross-breeding" as long as it is profitable. Indian cattle do not meet market demands for milk at all times of the year. To stop the importation of foreign cattle by legislation, as has been suggested, is not the solution. Milk production in urban centres would be greatly decreased, if no animals of foreign breeding were permitted. Some of the soundest dairy enterprises in India would virtually be driven out of business. The real solution is to seek to find out how to use foreign blood successfully in India to gain its benefits, but not reap the harmful effects attributed to "crossbreeding." There should not be a programme of continuous crossbreeding. Perhaps we should not aim to make a new breed, but rather to use the high milking qualities of Western cattle to improve the indigenous breeds of India. A method of doing this is discussed later.

Dairying in India will not make any significant advance as long as little or none of the organized effort is taken by private breeders. It will not advance very far as long as the only source of pedigreed dairy

bulls is Government farms, or purchased by Government cattle buyers on the basis of appearance in cattle-breeding areas. Every large commercial dairy farm in India should become a source of improved dairy sires for village use. Such farms usually keep records and can give pedigrees. The present efforts are but a drop in the bucket. Smith ('27) estimated that a million approved bulls were needed for breeding in India. The present number of Government bulls can make no significant impression on the cattle of the country. Wright ('37) suggests that the resources of the Government Military Dairy Farms, Pinjrapole and Gowshallas, and district and demonstration farms be added to the present sources for good dairy stock. The author would add *commercial dairy farms* to the list. The supply of breeding bulls might well become an important source of supplementary income to such farms. These farms are in the dairy business for money. They have selected the way in which they can produce milk economically and meet market demands Private dairymen cannot talk about the production of milk in any other way than to produce it "quickly" and "cheaply". They are interested in "short-cut" methods, and see no virtue in delay. No commercial farm can gather into one farm, selecting from thousands of recorded cattle, the best Indian cows, as was done to form the herd at the Ferozepur Government Military Dairy Farm (Smith '27). No commercial dairy farm can wait 20 years to breed a profitable dairy herd A foreign bull and crossbred cows do this in one generation. The four or five years necessary to begin to have a few crossbred cows paying an income is long enough for most commercial firms to wait. The problem for them, then, is how to use foreign breeding.

How to use "Crossbreeding"

After the initial use of a foreign bull and the establishment of a crossbred herd of cows, the breeder has his biggest problem of breeding. If it has not been considered before, it must be considered at this time. If this problem can be decided successfully, the majority of the complaints against "crossbreeding" will have been met. It cannot be said that this system "from the breeding point of view leads nowhere' (Smith '27). It is not possible only to extract milk from these cows without breeding them. A few strange instances of cows which gave milk without breeding have been reported, but it is not possible to carry on a dairy business in this way. It is fallacy to consider "breeding first crosses for commercial purposes" (Royal Commission '28) but not consider continuing them for breeding in any way. The functions of milk production and reproduction are inseparably bound together. To produce milk, calves must be born. Cows must be bred to produce calves worthy of living. No man can call himself a breeder and regard a bull simply as a "cow freshener." It will pay

the dairyman in India, as in most other parts of the world. to rear his own heifers for replacements in his herd.

The method of breeding crossbred cows is the crux of the whole matter of the success or failure of the introduction of foreign breeding. There are three general possibilities open to the owner of the crossbred herd. These are: —

1. Continue to grade to foreign bulls.
2. Interbreed the crossbred cattle.
3. Backcross to good Indian bulls.

Grading

Of these three possibilities, the first, if it is possible, is the simplest. Inferior cattle in Canada, United States, South America, South Africa, and Australia have been graded up by the use of better sires of the European breeds. Herds of imported breeds have been established in those countries and used to supply more breeding bulls as well as being economically more profitable animals in themselves. However, in India the question of climate intervenes. Indian cattle have survived Indian climatic conditions for centuries. They are a great living example of the "survival of the fittest." There has been natural selection, with very little opposing artificial selection by man, for the ability to withstand the heat, humidity, drought, irregular feed supply, and diseases of India. It is not to be supposed that a foreign breed or any animal containing a high percentage of foreign breeding can withstand these conditions as effectively as native cattle.

It is not necessary, on the other hand, to choose between the two extremes of low productivity with high resistance, and high productivity with little resistance. High-grade European cattle may be more productive, but the mortality may be so high that the advantages of regular calving, etc (MacGuckin '37) and high production in such animals would result in final loss. The degree to which a sheltered environment may be produced and controlled may determine the percentage of foreign breeding which can be introduced. The Government Military Dairy Farms, with many farms (distributed risk), well-trained staff, standardised rules (MacGuckin '33) veterinary care, and the best of modern equipment, may be successful in grading up to foreign bulls when the average dairyman would not. Breeders in general have not been successful in keeping herds of foreign cattle on the plains of India. A few individual animals have lived. Breeders do not favour grading to foreign bulls. All may not be successful even with the ideal environments and isolated herds like those maintained by the Government Military Dairy Farms. Foot-and-mouth disease and other diseases tend to be more serious the higher the percentage of foreign breeding.

Grading up with foreign bulls is not likely to be a successful method of helping village dairymen. These dairymen are the backbone of the dairy industry of the country. All measures to improve the livestock should keep these men in mind. It is necessary that better care be given to better animals (Carruth '21) whether they are improved Indian cattle (Kartha '33) (Matson '28) or all or part foreign. Improved Indian dairy cattle are more susceptible to disease than unimproved stock (Henderson '27).

In the symbiotic relationship (Schneider '20) (Baini Prashad '38) between man and cow, which is more evident in India than in many other countries, it is not to be expected that one of the participants in the symbiosis greatly increase its contribution unless the other does also. There is little hope for improved village dairying in India unless the cows produce more milk, and are fed and cared for better. The author agrees with the opponents of crossbreeding in their statements that it is too much to expect that Indian peasants should be able to give the care necessary for high-grade foreign cattle. However, he also believes that it is too much to expect gwalas (dairymen) to begin to feed their scrub cattle better in hope of obtaining more milk efficiently. It is an uneconomical proposition, and they will not feed any cows better until they have cows that respond to such better feeding by a sufficiently greater flow of milk. City gwalas, who are the cousins of the village gwalas, have learned to care for cows having not too large a proportion of foreign breeding. They consistently obtain much more milk and more profit from their cows. It should not be our object to make a new breed for India, but to improve its existing breeds. Grading to foreign cattle soon produces an animal of entirely foreign character. Such an animal is too distinctly different to adapt itself to Indian village conditions. It is not likely to succeed. It has not proved itself satisfactory generally outside of Government Military Dairy Farms, which are continuing to pursue the policy of grading. Grading to foreign bulls is not satisfactory for other dairy herds, and certainly not suitable as a method of improving village cattle.

Interbreeding Crossbreds

Second : Breeding crossbreds together causes the most variation. As mentioned in a former paragraph, if the breeder desires to improve his cattle by selection, he must have the character desired in order to select it. If he has the character present in his stock to the desired intensity, he can select cattle capable of demonstrating the character themselves, and passing it on to their offspring. Unless he has sufficient variation in the direction in which he desires to select, he cannot select better and better animals in that respect. He must have variation toward what he considers to be better. Variation is a good

thing. Variation is the material upon which the breeder may use the tool of selection. He depends on variation. Without it he can do nothing to improve his animals. However, when crossbred animals are mated together, there is too much variation unless huge numbers of animals are used. Such matings cause variation out of control, and only astronomical numbers would cover all possibilities.

The chief objective of breeding to foreign dairy bulls is to introduce variation, variation in the direction of higher milk yield. However, interbreeding crossbreds causes variation in all directions, all directions at once, in one generation. Variation is like fire ; it is a good thing when it is kept within limits. Children should not play with fire. Fire in a stove is a good thing, but when it sweeps through an Indian village it is a bad thing. Some persons who have tried to interbreed crossbred (F_1) cattle have been burned, and will be forever afraid of crossbreeding.

In an F_2 generation, it is possible to have any combination of characteristics present in either or both of the breeds originally crossbred. There are possibilities of having any combination of good and bad, a complete assortment, a medley, of anything found in either or both breeds. There are possibilities of any combination in the polynomial theorem. Probably enough animals would never be bred to have all combinations of characters. It is possible to have in one animal all the worst characters of both breeds. It is equally possible, theoretically, to have in one animal all the best characters of both breeds. However, the hope of obtaining such an animal is so small that it is not worth the attempt except with large numbers of cattle. It has not even a sporting chance in a herd of ordinary size. Those who attempt to improve Indian cattle by introducing foreign breeding in the future will be disillusioned of this possibility, unless (as has been suggested by many others) an extremely large, well-financed, long-time, breeding plan along these lines be set up.

Not only are all combinations of good and bad possible if there are enough animals (which there never would be even if all the cows in India were crossbred and their offspring interbred), but also many factors which are good in one combination are bad in another. Asymmetrical offspring are very common. The various parts of the body do not harmonize. The usual relationships and proportions are broken up, and such animals appear very poor to the judge of dairy cattle. From the showring standpoint, such animals are often very bad To the man who has an eye for good càttle, they are especially distasteful.

Only the F_1 generation is successful, since every desirable dominant character from both parents comes into play. An F_2 generation is like putting two watches together. There is a mixture of sizes, shapes, and qualities of parts, and relative efficiencies of various parts of the anatomy of the two breeds show up. Parts of two makes of

watches do not have the flexibility of animal organs, but even so there is a limit to the adaptability and mutual inter-locking in function of the body parts in the F_2 generation of two widely different breeds.

Forman ('27) states, "Crossing has a tendency to break up established characters. It destroys combinations of characters which have long existed in the strains and which under the system of pure breeding have behaved in a manner like unit characters in transmission."

Jeremy ('28) writes, "Most breeders agree that their object is satisfactorily attained in the result of the first cross (called the F_1 generation), the half bred animal being a good milker and fairly resistant. This shows that both milk giving qualities and immunity are doninant characters, since they regularly manifest themselves in the first generation. But complications arise when the half breds are inter-bred, the second or F_2 generation being in most cases animals of poor constitution and milk yield."

Henderson ('27) writes regarding breeding Sahiwal cattle at Pusa, "For years the practice has been to reject all animals giving less than 4,000 lb. of milk in a lactation period of 10 months. The number of rejections has been nearly 75 per cent. These rejected cows were either sold or crossed by our imported pedigree Ayrshire bull. Almost all the 'first' crosses have been very good, ten of those in milk at present have averaged 7,651lb of milk in a 10 month lactation period. This represents an averaged increased yield over their Montgomery dams of 4,627 lb. each per lactation of 10 months. The half-breed animals are hardy and 'good doers'. In a recent outbreak of foot and mouth disease, they were actually less affected than the pure Montgomery stock......

"Unfortunately these excellent results are not maintained when the 'half-breds' are mated with 'half-breds'. The so-called double crosses thus produced are poor milkers and lack uniformity of type. They are in fact failures from the breeder's point of view......"

Smith ('27) testified before the Royal Commission on Agriculture. "The F_2 is useless. We bred about 140 of them before the Civil Department took it over, and I think we got about five good cows out of the lot."

If the breeder is selecting for uniformity and for all the points of body conformation, as well as for milk production, certainly five good cows is a very good proportion to obtain in a F_2 generation of one hundred forty. If these results could be increased twenty or fifty times and obtain the same proportion of good cows, an excellent herd to carry on would be obtained. Often hopes have gone so high with the F_1 cows that, when the average of F_2 generation falls so short of the F_1 standard, it is difficult to see that they still excell local cattle and that certain individuals greatly excell the rest. The surprising thing is, however, that in spite of their undesirability and

lack of symmetry, F_2 animals are usually better milk producers than the ordinary Indian cattle of the locality from which the parental stock came. Government farms have consistently bred only the poorest Indian cows to bulls of the same Indian breed, so that the worst types have segregated out in the F_2 generation. City gwalas continue to breed F_{II}'s and find them profitable. However, such animals are certainly more inclined to weaknesses, and some of the most dejected individuals one may ever see are among such second generation animals. Somehow, one expects more of animals of foreign breeding, and the animals look worse because they resemble well-known European breeds. Many poor Indian cows look fully as bad, if not worse. It has never been demonstrated that such mongrel cattle are any worse than many of the local native cattle with which they have part of their ancestry in common. Persons unfamiliar with western breed types and standards are not as shocked if such animals do not greatly excell the local cattle.

The author is aware of the method of founding the Corriedale breed of sheep (Hultz '40). However, when F_1 Merino-Lincoln sheep were interbred, large numbers were used, and careful selection and drastic culling were carried out to establish characters demonstrated by both sexes. Success was achieved within the lifetime of a group of enthusiastic breeders. This was possible because of the shorter life cycle of sheep. To accomplish equal success with dairy cattle would require more capital outlay, the income from which should continue uninterrupted over a much longer period. Leadership, continuity of policy, and vision of the importance of the task must continue much longer than the lifetime of the men who would found such an extensive experiment with cattle. Corriedale sheep were founded by private capital with vision. Indian attempts with cattle have been financed by Government funds which have always appeared to be subject to changing policies of a changing personnel Theoretically such a breeding project would succeed if properly planned and executed, but as yet no benefactor has come forward with the necessary capital to use this method of benefiting future generations in India. Unless adequate funds are assured, this plan of breeding cannot be accepted as a feasible means of breeding dairy cattle capable of supplying India's need of milk.

To summarize, we can say it is from this interbreeding of crossbred animals that "crossbreeding" has received its worst condemnation. The worst types of animals are invariably of this breeding. It is not to be recommended unless thousands of animals for selection can be bred. Inheritance depends on chance. The good breeder can learn to manipulate his matings so as to bring the chances more in his favour, but the man with a small herd and limited capital who interbreeds crossbreds is the most reckless of gamblers. Such animals are the cause of most of the predjudice against "crossbreeding."

Backcrossing to good Indian Bulls

Grading to foreign bulls does not produce an animal suitable for Indian dairymen. Interbreeding crossbreds produces undesirable types But there is a third general possibility which can be carried out in moderate sized herds and with limited funds. We must breed our crossbred cows back to good Indian bulls. By breeding to good Indian bulls of the same breed as the foundation herd of Indian cows, racial stability is given to the offspring, the inheritance of Western cattle which makes them less suited to Indian climatic conditions is decreased by half each generation, while part of the desirable characters of high milk production can be preserved and increased by selection in those families which continue to show the high yield of the first crossbred.

This method of breeding was suggested by Matson ('28, '29) who based his judgment on extensive experience and data with many "back-cross" animals. MacGuckin ('37), calling it "grading down," gives it as one of the acceptable procedures and present records of milk yields for such animals. Buchanan Smith ('31), who suggests four ways of improving tropical cattle, mentions the "infusion of a specific character", which could be accomplished by this method. Henderson ('27) advocates this plan of breeding from his observations at Pusa. Littlewood ('33) is "of the opinion that this is probably the better method" and presents data which support this view. Hutchinson and Joshi ('37) advocate backcrossing as the only system of breeding crossbred cattle likely to be successful in small herds and present cogent arguments in its favour. The author agrees.

There are two general methods by which the cattle of India as a whole may be improved in milk production :

1. By continued selective breeding of Indian breeds, a slow method which may have a limit to the amount of milk yield to be obtained.

2. By outcrossing to suitable foreign bulls and backcrossing to good Indian bulls.

At the thirtieth meeting of the Board of Agriculture, 1924, it was recommended that "half bred Ayrshire-Sahiwal cows should be sired by a first class Montgomery bull of milking strain with view to maintaining the milking qualities of the half bred and restoring the immunity to disease of the Sahiwal." It would have been well if this plan had been carried out in the Pusa herd and other Government herds in India instead of discarding cattle of known breeding and losing the benefits of much constructive work.

Lush ('33) reports that in Texas animals having 3/8 of Zebu breeding are best for meeting the local climatic and market conditions. In a more equable island climate in British West Indies, Hammond ('31) and Edwards ('32) show that $\frac{1}{4}$ of Indian blood is enough. If a

blend of the two sub-species is of value to other countries to breed a more hardy and a more productive animal, it is only logical that it may be true in India, also. However, in the native home of the Zebu it is reasonable to suppose that *a much higher proportion of Indian blood than in other countries* would be necessary to make a successful animal. The environment which has produced such animals will require more hardy animals to live there.

Sikka ('33) makes an excellent introduction to an article as follows: "That Indian cattle are low yielders, and therefore uneconomical producers of milk is widely recognised. The high milking qualities of the cross-breds, which makes them economical producers of milk are also generally admitted ..... the first cross has invariably been highly successful, and the half-bred Indian-European cattle have always been good and economical producers of milk, but later crosses with the imported sire or double crosses, have admittedly been disappointing—at least those with the Ayrshire breed."

The success of the crossbred cow and the failure of the two methods of breeding her are well stated by Sikka, but he has omitted the third possibility which follows in natural sequence: *Breeding the crossbred cow to good Indian bulls* ! Many workers stopped short of this, and much valuable, incomplete research material was discarded. For a period there was a great interest in "crossbreeding." A glance at the citations listed at the end of this article will reveal in some degree the number of publications on the subject in the Indian Animal Husbandry literature of that period. However, to be successful, the utilization of foreign breeding to improve Indian cattle requires as much patience and steadfastness as selective breeding with Indian cattle.

The term "outcrossing" is commonly used when cattle, which formerly have been line-bred, are bred out to a bull of another line, family, or strain within the breed. The author wishes to suggest this term for the form of breeding advocated in this article, although "outcrossing" usually is used only for matings within a breed. The term "outcrossing" is especially applicable here in that the breeder breeds out to a sire of another breed *with the specific intention of returning to and following his former line of breeding.* It is advocated that commercial dairymen who need more milk than is produced by their present herd of Indian cows *outcross* to suitable foreign bulls, with the specific intention of returning to their former line of breeding using the best bulls available of the Indian breed which is maintained. It may or may not be part of the plan thereafter to use sires having any foreign breeding. Decision regarding this point may depend on later evidence. Research should be planned to test the best percentage of foreign breeding to plan to leave in the Indian breed. Possibly in some cases, sires having $\frac{1}{4}$ or more foreign breeding may never be used again.

MacGuckin ('37) states: "For practical purposes, it may be assumed that, if an animal has not less than 31/32 of the blood of one breed it is a purebred." In four generations after cross-breeding this stage might be reached: But the animals would have *passed one or more highly profitable generations.* Many valuable genes, even though any one animal may have on the average only 1/32 of such genes introduced by outcrossing, will have been introduced into the breed. *Selection of cows on the basis of milk production will tend to retain those genes most valuable for high milk yield.* Such valuable genes, therefore, will be far more numerous in the herd than might be the case from chance alone. *Selection is more effective after outcrossing.* Seeking high-producing cows is like "looking for needles in a hay stack." It is really seeking for animals which have the genes for high production, for the genes which are the units of inheritance are actually the "needles" we seek in the dark. The author is much more inclined to look for needles in a hay stack if he knows that some have been placed there. An outcross to a foreign bull is much more apt to make selection fruitful. Knowing that one's herd has an infusion of genes from the best of foreign breeding opens the roof. The curve of selection progress in Indian cattle indicates that there is a low ceiling of production through which Indian cattle may not break. *Outcrossing breaks that ceiling.* Outcrossing also permits the cattle of commercial dairy herds that have been crossbred, *which must pay their way,* to return into the main stream of germ plasm of a great All-India breeding plan. Crossbred herds at present continue to be *in* India, but not *of* India! Backcrossing makes them part of India. They become as the water of the Ganges, diverted for economic purposes, returning to the main stream.

If a breeder is skillful and understands his work (he knows he is playing with fire, but is confident that he knows how), he may cautiously use sires of less than half foreign breeding, on cows of similar breeding Until such bulls are used, there will need to be no selection against undesirable characters possibly introduced by the outcross to the foreign bull. The number of such undesirable characters is halved by each generation of backcrossing in any case. All the harm of which "crossbreeding" is accused has no opportunity to express itself. As long as backcrossing is continued, no animals will result which are worse than would be bred in any case if there had been no outcross and pure Indian breeding followed throughout. In the opinion of the author, bulls having less than half foreign breeding should be used early in this programme.

When animals having a small fraction of foreign breeding are interbred, undesirable characters may crop out from time to time, but the proportion of these would not be so high as to affect seriously the culling percentage. The situation would never be out-of-hand. Variation would be under control. The widely different types and

uncontrolled variation noted by interbreeding "first crosses" would never occur. The bad results of an F_2 generation or the question of the inadvisability of high-grade foreign cattle in an Indian environment need never arise.

The experience of many breeders has been that backcross animals (to the Indian bull) are often very rugged and thrifty. This has been the experience in the herd of the Allahabad Agricultural Institute. MacGuckin ('37) mentions this in his report. Matson ('29) notes that about 10 to 11 per cent of quarter bred foreign animals are exceptionally hardy. From his many close observations he postulates four genetic factors affecting the thriftiness of Indian and Western cattle:

E—Relatively low "extractive" power (ability to digest and extract nutrients and to be maintained by poor-quality roughages) of European cattle.

e—Relatively high extractive power of Indian cattle.

C—Capacity of European cattle to utilize large quantities of feed for production and rapid growth.

c—Relatively low capacity of Indian cattle.

Matson suggests that these factors are linked with 10 to 11 per cent crossing over. Therefore the cross and backcross of European and Indian cattle involving these genes might be shown as follows:

CE/CE European	×	ce/ce Indian	=	CE/ce, (F)						
ce/ce Indian	×	CE/ce (F_1)	=	Ce/ce 10 to 11% Very thrifty	+	CE/ce 78 to 80% Average in thriftiness	+	ce/ce	+	cE/ce 10 to 11% Unthrifty.

Matson calls attention to the ability of these "super-normal" animals to "combine the high milk yielding power of the European with the climatic toleration and efficient metabolism of the Indian.' He states that in backcross animals the resistance to infectious diseases "is certainly as high as in the pure Indian". The recent comparisons by French ('40) in actual digestion trials appear to explode the idea of the superior digestive ability of Indian cattle, which has been supported by nearly all practical observers in India. It is possible that the animals used by French were not typical individuals. Whether or not the letters assigned by Matson are actually genes may be doubted, but the general characteristics of "C" and "e" have been attested by many.

One of the chief objections to backcrossing as advocated herein is that the average milk production is decreased below that of the crossbred. This is recognised, but the fact that the quarterbred and

one-eighth bred offspring have greater constitution, are more suited to the country, and have stability in breeding (when bred to good Indian bulls) makes this system attractive. It is the only possibility remaining for the man who has a small herd of crossbreds and wants to follow a safe, conservative, permanent plan of breeding, seeking to build a herd suitable to be indigenous without discarding his profitable crossbred cows and purchasing expensive and (or) unprofitable cows. However, a significant fact is that some backcross cows produce fully as much milk as the crossbred cows (Littlewood '33). While the foreign inheritance on the average has been cut in half, the animal has inherited enough genes and in such combination to have milk yield equally high as the F_1 parent. The selection of these animals builds a herd which is high-yielding, relatively true breeding, and indigenous.

Another significant fact is that herds produced by backcrossing cressbred cows to good Indian bulls do not fall as low in milk production for several generations of backcrossing as would be the case if an outcross had never been made. This is sometimes lost sight of in comparison with the startling increase in yield in the first cross. However, the breeder who outcrosses for milk production knows this, anticipates it, and is not worried if he does get a decrease in milk yield He knows he is on safe ground and that he has taken all that he can hope to take from the outcross, and keep a continuous breeding herd. Further, he knows that he can conserve much of the high production of the original crossbred by selection among his backcross animals, but that they do not have the serious breeding limitations of crossbred cows.

The fact that the backcross animals never average as low as the original Indian cows is of greater importance if the plan is to breed only the poorest Indian cows to a foreign bull. This is advocated by several authorities, and even some of the present day opponents of "crossbreeding" acknowledge* that the poorest cows in dairy herds should be bred to foreign bulls. Henderson ('27) reported that at Pusa "rejected cows were either sold or crossed by an imported pedigree Ayrshire bull." There might be a difference of opinion as to just how poor the cows must be to breed to foreign bulls, and also as to the future breeding policy after the outcross. Opponents of crossbreeding may favour discarding calves in later generations, while those who favour outcrossing believe in re-assimilating all worthy family lines into the breeding herd.

Matson, from his wide experience with thousands of crossbred and Indian cattle, writes ('28) "..... the man who sets out to supply a demand for which he must buy 100 cows will inevitably include in that 100 a large number which, while they conform fairly closely to the selected type, will yield substantially less than the average and he will produce a certain further number of these in breeding up the herd

*Private conversation with the author.

generally. The average yield of his initial herd, if he has taken great trouble in the buying, may possibly be 3,600 lbs. By mating his below-average cows with a good European bull, they should produce heifers which will yield 6,000 lbs. at maturity These in turn mated with Indian bulls bred from the best cows will produce cows equal to the average of his original herd .....They are very thrifty cattle......In this way the herd average should be brought up to 5,000 lbs, a high figure for an annual average in India, within a comparatively short time, whereas adhering to indigenous blood will certainly entail a wait of 16 to 20 years and there is considerable risk that it will not be accomplished even then. ....

"That is the only method of working with European bulls that I can recommend if the Indian foundation stock is of either Sahiwal or Sindhi type.... ......"

Geneticists may point out that although high producing cows may continue to be selected while backcrossing is continued, they certainly will be heterozygous for every gene for milk yield received from the outcross. This is true, but fewer animal breeders are talking of "homozygous sires" etc, with the same hope as a few years ago It is recognised that it is better to have animals having *some* good genes, even though heterozygous, than to have animals homozygous for mediocrity. There is no possibility of "breeding out" undesirable traits in a herd if they are homozygous. A certain amount of homozygosity is desirable and necessary if a herd is to be "true breeding", although there are probably many heterozygous animals which apparently breed true for certain characters simply because there is little difference between allelic genes.

The essence of this method of breeding is that after outcrossing for milk production the animals are bred back to stability, resistance, and adaptability to Indian conditions, while selection may be confined largely to milk production. The breeder need not be distracted from selecting only for milk yield by being compelled to select for many other points. No attempt is made at this time to decide how many generations of backcrossing should be continued before using bulls of backcross breeding. The breeder will have to decide this on the basis of his observations in his own herd, or from research on this subject. The author would postulate that the most resistant and productive animals would have between 1/8 and 3/8 of foreign breeding.

Outcrossing vs. Grading to Foreign Bulls

If the herd is graded to foreign bulls, then it is necessary to select for points of constitution while breeding for milk production (MacGuckin '37). Milk production can be measured. It is a character with a constant, everyday, quantitative expression. Constitution cannot be measured with relation to climate. Environment is not unvarying.

High-grade foreign animals may apparently acquire immunity to many diseases while the breeder continues to breed them generation by generation farther and farther away from the resistance of native animals. Then a sweeping epidemic may eliminate them all. Exposure to disease is not a constant element in the environment It is impossible to measure the ability of cattle to withstand natural exposure, unless they are deliberately exposed to infection regularly. This would mean keeping the cattle under much less sheltered conditions than is prevalent at Government Military Dairy Farms and on other farms practicing grading to foreign bulls. It might mean such high mortality as to make this system of breeding untenable. It is not practicable to subject such animals to an Indian village environment. Therefore, the breeder who grades to foreign bulls must be aware that his herds are in danger of great and sudden mortality from some Indian disease to which his high grades do not have resistance.

There are situations in India under which grading to foreign bulls may be advisable and worth the risk. The Government Military Dairy Farms may be considered one of them. The author has been advising the breeding operations of a large herd for several years, in which continued breeding to foreign sires has been recommended and is being carried out Such farms cannot be expected to discard their foreign cattle and breed only Indian cattle. The method of breeding advocated herein might be a possible compromise, if and when enough satisfactory Indian bulls are available for backcrossing This would enable the military herds and private dairy farms to make their contribution to the livestock of the country without the upheaval of dispersing many valuable crossbred cows and purchasing in their place Indian cows of questionable merit.

The Crossbred Bull

One big misunderstanding is the crossbred bull. He has been much maligned True, he has his shortcomings, but he has his value. (Matson '28) Whatever poor offspring there may be caused by mating crossbred cows with crossbred bulls is equally the fault of the crossbred cows. The bull cannot be blamed entirely for the poor results. The cows to which he is mated must share the blame.

Crossbred bulls can be used with success on Indian cows (Matson '28) (Carruth '21) If a crossbred bull is bred to a purebred cow of the same breed as his dam, few or none of the faults usually attributed to him appear. The breeder must realize that the crossbred bull has good genes. In fact, half of his genes are from his foreign sire If his Indian dam was a high producing cow, then he is better also. The crossbred bull is certainly a more risky proposition if the policy has been to breed only the poor Indian cows to foreign bulls The sperms from a crossbred bull contain a random half of all genes he has. At

times, through chance, his offspring may approach those of the foreign bull (Matson '28). It is possible that some of his offspring may even be "supernormal" as described in a former paragraph. His daughters *may* receive only the most beneficial genes from the foreign ancestry, genes for high milk yield, etc., and few or none of the undesirable "foreign" genes. They may also receive in a certain percentage of cases only the poorer genes which the foreign ancestry has to offer. The saving fact in backcrossing is that the introduced variation on the average is only one-fourth of the full genotype of the offspring.

There is one loss in using a crossbred bull which is not lost in backcrossing a crossbred cow. The sex-linked inheritance Such genes for high milk production inherited from the imported sire as may be carried on the sex chromosome, the crossbred cow gives to approximately half of her offspring. The crossbred bull, however, has none of them (as his sex chromosome has come from his Indian dam) and gives none of them to his offspring. This may or may not be significant. Considering the great disparity between the milk yield of Indian and foreign cattle, the ruling out of one chromosome which might carry genes for the high production of the foreign breed may not make a serious difference in the milk production of the quarterbred female offspring. There is probably no more difference than "uneesbees ka farq*". This point is fully discussed by Hutchinson and Joshi (37).

Outcrossing in Practice

It is said that all of these plans are satisfactory when the "crossbreeding experiment" can be controlled, but several instances have been cited in which there was no control. Simple rules can be learned by gwalas, such as: "Never inter-breed crossbreds" "Never use a bull having foreign breeding more than one generation" Several gwalas in Allahabad have learned this lesson after the author had pointed out the disastrous results of such breeding among their few cattle. Control is to be preferred, but time tends to develop and combine what man wants (milk production) with the requirements of the environment, Man selects for milk production ; nature selects for "survival value."

The Foreign Breed to use

The author believes it quite possible to introduce a small amount of foreign breeding into certain Indian breeds, which after several generations would never be suspected by the most severe critics (except possibly from increased milk yield). Further study is necessary before stating the exact percentage of foreign breeding best adapted to each of several Indian conditions. A fraction of Holstein-Friesian breeding might be introduced into the Dhunni breed with profit. Jersey,

*An Indian proverb; translation, "A difference of 19 and 20."

Brown-Swiss, or Danish Red breeding might be infused in small amounts into any one of several breeds Other combinations might be suggested. It is important that the foreign breed do not introduce too many irrelevant or harmful variations against which selection must later be practiced. The foreign breed must be as similar as possible to the Indian breed which is outcrossed. Joshi ('27) in his testimony before the Royal Commission on Agriculture stated, "Without having dealt with the indigenous breeds by themselves, it was wrong to have paid so much attention to crossbreeding." His complaint clearly was not against crossbreeding as such, but because it was being pursued without reference to the type of Indian cattle. The chief difference of the foreign breed should be the difference which the breeder wants to introduce (in this case, milk yield). If such a bull existed, a bull which is different from the cow herd in no respect except those respects which need to be improved, should be used.

There is no longer a need for an experiment design to "try out" different foreign breeds. However, it is generally agreed that the Government Military Dairy Farms made no mistake when they changed from the Ayrshire, and found the Holstein Friesian breed more satisfactory. Also other workers* have stated that animals containing various percentages of Guernsey breeding are relatively less suited to the tropical climate then animals of Holstein-Friesian, Jersey, or Brown Swiss breeding (Morrison '37). However, the problem is not simply one of trying this breed or that in combination with certain Indian breeds and getting a clear, straightforward answer. The individual bulls imported and the method of breeding are as important as the breed. Having selected the Indian breed with which he desires to work, the breeder should consider which foreign breed introduces the most milk production, but disrupts the type of the Indian breed the least. Wide differences in colour, body form, size, butterfat percentage, etc., should be avoided unless those variations are desired in the improved animal of the future. This should be the attitude particularly if out crossing as advocated herein is followed. (If the method is to be grading to foreign bulls, the foreign breed can be selected with less reference to the type of the Indian cow herd). Unwanted characteristics will have to be culled out. It is better not to introduce them if a uniform, truebreeding herd is wanted in the future. Usually the choice of the breed of foreign bull may be made by an informed breeder on *a priori* reasons alone. Lengthy experimentation on this will not be necessary. The selection of the individual bull is more important. Our plan is: by one outcross to a foreign bull to introduce the desired genes for high milk yield. Because we make only one outcross to a foreign bull, we should be even more careful in his selection. If we, so to speak, give only one shot of superior foreign blood, it is important that that one be the very best.

*Personal communication to the author.

Market demands cannot be ignored in selecting the foreign bull. The Allahabad Agricultural Institute has discovered that milk from Holstein-Friesian crossbred cows does not sell readily in the open Indian market. Persons educated to appreciate cleanliness may buy milk from a modern city dairy in spite of its being of lower butterfat content. The Indian market often has a taste for buffalo milk which may average about 7 per cent. There is a misconception regarding the "high" butterfat percentage of Indian cows' milk. Half-starved cows may secrete milk high in fat and total solids (Gowon and Tobey '31); Overman and Wright '27), but the normal secretion of well-fed, high-producing Indian cows is not particularly rich in butterfat Tests by the Allahabad Agricultural Institute do not show Indian cows' milk to be superior to "crossbred" cows' milk or to the average butterfat percentages reported by Nystrom ('32).

Outcrossing at the Allahabad Agricultural Institute

When the Allahabad Agricultural Institute took stock of its cattle breeding operations in 1934, it was noted that of all Indian breeds which had been tried, the Sindhi had done the best. As there is no good dairy breed native to Allahabad district, it had been thought necessary to try out several such Indian breeds. Sindhi cows adapted themselves well to the climate. There were several good milk producers among them. The number of animals in the Sindhi herd increased, while the number of animals of other breeds decreased. Whenever it had been necessary to cull Indian cows because they were unprofitable (which was often), it had been Sindhis less frequently than other breeds. There were more Sindhi cows and crossbreds with Sindhi breeding than any other. There were cows of the following breeding: Sindhi, Holstein-Sindhi, Guernsey-Sindhi, Jersey-Sindhi, and Brown Swiss-Sindhi. These were the progeny of earlier work to test the relative merits of the different European breeds under local conditions The problem was to unify this very heterogeneous herd. The solution was to backcross. *Thus backcrossing became not only a studied breeding policy, but also a useful expedient to unify the herd!* The alternative was to discard all of this mixed herd, made up of a number of excellent individuals, and try to buy a uniform herd which livestock men know is next to impossible. A few remaining Indian cows of breeds other than Sindhi were disposed of, but all good individuals were retained. Disposing of the mixed crossbred herd and buying more indigenous cows (as done by many farms when advised to dispose of crossbred stock) would have been an expensive proposition, and phonotypically uniform animals purchased in cattle breeding areas do not usually produce as uniform offspring as themselves. The percentage of failures among purchased animals is usually high, even when bought by the best of cattle judges. Our miscellaneous crossbred herd had (with a few exceptions) one thing in common: Sindhi

breeding. The backcross animals differed from one another in only one-fourth of their breed background and were all three-fourths Sindhi. It was surprising to note the increase in uniformity obtained n the first backcross generation. Each backcross to the same Sindhi breeding brings them closer and closer together. This is a very useful process for any mixed herd It is commended to all who still have mixed crossbred herds

Crossbreds as draught bullocks

It is often stated that crossbred bullocks make poor work animals. The object of outcrossing is not to produce work bullocks. India has as fine oxen for draught as any country in the world. It is not so evident that any foreign breeding is needed to make improvement in this respect. However, it must be recognised that approximately half of the offspring will be male. If these are reared and not used as breeding bulls, they may be used as draught animals Usually it is too expensive to rear male calves on specialized dairy farms. Milk that has a ready sale at retail prices is too expensive to feed to any but calves reared for breeding. Male calves other than valuable breeding stock, reared on such farms, are probably never worth at any stage of life what they have cost in feed and labour (Johnston and Singh '30). It is cheaper to buy work stock. Nevertheless, as an experimental measure only, a number of crossbred bullocks have been reared by the Allahabad Agricultural Institute. Some of these have been in work in the fields for ten or more years. They have done very satisfactorily, and are superior to local village bullocks. They have not been pampered in any way. There have been approximately twenty crossbred bullocks working daily on the farm in the hot sun of summer days in temperatures ranging up to 118° F. They have done all kinds of work including ploughing, harrowing, levelling, pulling carts, etc.

Other outcrosses

History is replete with instances of outcrosses. It has been rumoured that the early English breeders outcrossed to acquire for their livestock the characters they desired. Bakewell (Lush '37) was said to have a mysterious ram which he kept hidden. Although sheep breed at a more rapid rate and higher percentages of offspring may be culled, it is improbable that Bakewell interbred the F_1 generation. He made only a single outcross to acquire for his sheep the character or characters desired. He did not reveal his breeding practices as there was a great deal of prejudice against outcrossing and inbreeding.

It is customary to consider as "purebred" animals of a certain type purchased in the cattle breeding areas of India, although those same areas may have many scrubs bulls and bulls of other types at large with the cows. Outcrosses deliberately made to foreign bulls to

introduce valuable economic factors could be no worse than the many unrecorded outcrosses to stray scrub bulls.

Some persons speak of some of the introductions of foreign cattle as failures, because a distinct foreign type has not been developed in a locality. If the distinctiven ss of the type of foreign cattle has worn off after several generations, that is as it should be The genes for higher production are there, although somewhat diluted, and they continue to act as a leaven of the whole, which pervades all of the germ plasm of the cattle in the area wherever they are bred. Variation, but not too much variation, has been introduced. Gradual selection for higher milk production can progress

In every section of the world which has a distinct type of cattle, there have been outcrosses at some time in their history. Invading armies brought cattle with them, and took captured cattle back after conquest. The result of such breeding thus was largely in the nature of an outcross. The same armies often caused a similar infusion of racial characters among the people in the invaded countries, or took hostages back to their homes with them. These instances were of the nature of outcrosses, not continuous crossbreeding.

The Hebrews are considered one of the most characteristic human races known Marriage has always taken place most frequently within the race, yet there are many instances of outcrosses (Genesis, Exodus). The infused characters of the other races were assimilated and those which survived contributed toward making the present-day Jew. Certain types were preferred and selection among human beings was practiced by giving desirable positions to those who conformed, and exile or death to those who did not (Leviticus).

SUMMARY AND CONCLUSIONS

There is need of doing more than has been done to supply milk adequately to the under-nourished and dominantly vegetarian population of India. Milk is one of the most acceptable foods and one generally stated by nutritionists to be most needed. The great disparity in the milk yields obtainable from Indian and foreign dairy breeds lends weight to the evidence that germ plasm from the latter should be used to increase milk production in India. Unusual conditions demand unusual procedures, and there are more reasons for over-riding the prejudices against "crossbreeding" in India than in countries where the existing cattle have indicated greater potential milk-producing capacity.

It is not necessary to choose between the extremes of the high milk yield with low resistance of dairy breeds of European origln and the low milk yield with high resistance to tropical conditions of Indian cattle. Variation introduced by means of imported sires should be strictly

limited by backcrossing the F_1 cows to good bulls of the same Indian breed as the original cow herd. Unless an extremely large, well-planned, and well-financed, long time breeding project can be undertaken, no F_2 generation should be bred. The wastefulness of discarding many female calves should be discontinued by commercial dairies. The exact percentage of foreign blood to be infused has not been determined; it will depend upon future observation, but it is certainly less than 50 per cent. All private and Government farms breeding dairy cattle throughout India should be consulted, enlisted, and encouraged to modify their policies so that their breeding operations will fit into a permanent breeding plan to supply bulls to other dairymen and thus be mutually helpful to all.

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With the present production of milk in India, the *per capita* consumption comes to only a little over 6 oz per day. In other countries, people consume more than five times this quantity. In India, the poor do not get even 6 oz. and, in fact, many of them have to go completely without milk or its products. Nevertheless, dairying is one of the most important cottage industries of the country and the value of the present production of milk is estimated at over Rs. 180 crores per annum.

Report on the Marketing of Milk in India and Burma, 1941.

THE COST OF PRODUCING MILK AND BUTTER FAT

By

D. K. Joshi, N. R. Joshi and James N. Warner.

INTRODUCTION.

The question of costs demands the attention of those responsible for any business enterprise in order that its activities may be carefully and, if possible, profitably guided. The accounting system of even a small organisation must be rather detailed so that it will show accurate costs on each product, unit or sub-division. It includes, therefore, a number of parts, one may say, which are useful separately from the remainder of the system. These different parts may be grouped in any desired way and summarised to allow the financial operations of a certain aspect of the work to be studied. It is such a summary of a group of the different accounts of the Department of Animal Husbandry and Dairying at the Agricultural Institute at Allahabad that is discussed in this paper.

Dairies and dairy farms in India may, for our purpose, be classified into four types, *viz.*, military, experimental, educational and commercial, of which two or more types may be represented in a single organization. The Agricultural Institute Dairy is a combination of the last three. As would be expected, this necessitates a system of accounts more detailed than any one of these types might require. In order, therefore, to present a statement of costs of a purely commercial order, certain modifications of the system actually in use must be made. Wherever this has occured it is explained.

This study was begun in the winter of 1941 in order to show as accurately as possible the cost of maintaining one cow, of producing one hundred pounds of milk and of producing one pound of butter fat respectively in the Institute herd. It was particularly designed to show the comparison of these costs between the Red Sindhi, Jersey-Sindhi and ¼Jersey-Sindhi zebus and the Murrah buffalo cows.

Departmental Debits

Animals and their care:

The accounts at the Institute separate female young stock from milk stock. At the time of first calving each heifer is transferred from the female young stock inventory to the milk stock inventory at a figure equal to the cost of raising her to that age at which transfer takes place. In making certain parts of this study, calves under six months were considered separately, although they are included in the female young stock inventory from birth.

Morrison* considers 1,000 pounds of live weight of cows, bulls and young stock as one mature animal unit. The following table gives a classification of the Agricultural Institute herd as it existed in 1940. It includes the average monthly number of animals in each class, their average body weight, the mature animal units represented per head and the average monthly number of mature animal units in each class.

	Average monthly number.	Average body weight	Mature animal units per head	Average monthly number of mature animal units
Bulls	15·10	1,000 lbs.	1·0	15·10
Buffalo cows ..	21·16	1,000 ,,	1 0	21·16
Zebu cows ..	91·30	700 ,,	0·7	63·9[illegible]
Young stock ..	89·20	400 ,,	0·4	35·68
Calves	29·90	100 ,,	0·1	2·99
Totals	246·66	..	..	138·84

Certain records are kept for each individual animal in the Institute herd. These are milk production, fat production, depreciation and feeding records. Others are kept for the whole herd for a period and then divided among individuals on the basis of the number of months they were present during the period. Such items are light, water, labour, supervision, equipment depreciation, building and equipment repairs and miscellaneous charges. Bull service charges are distributed as explained later.

At birth or purchase each animal is given a number which distinguishes it thereafter. It may or may not be given a name. The individual records are kept on the basis of the animal's number A summary of all records is kept on a permanent history record card. The date of birth, and therefore the date of calving of the dam, gives the basis of determining the months on test, the days in milk and the days dry during the year.

The standard practice is to milk those animals three times daily which give ten pounds or more of milk in 24 hours; others only two times.

At each milking the milk produced by each animal is weighed to the nearest tenth of a pound and recorded. The milk produced during the first three days, that is the colostrum, is not included in the monthly totals, derived from the yields at each milking. Once each month a composite sample is taken of the milk produced during a twenty-four hour period for testing for fat by the Gerber method. The product of the monthly milk yield and the fat percentage so determined gives the fat production in pounds for the month.

*1 Morrison, F. B. (1936). Feeds and Feeding. 20th edition.

The Institute has no grazing land. It is necessary, therefore, to feed and care for all animals in the paddocks and barn. Cows are left in the milking barns during the hot part of the day in the summer and the cold part of the night in the winter. Otherwise, they are in the paddocks, except at milking time. Morrison's feeding standard is followed as closely as possible. Roughages consisted of green napier or guinea grass; silage made from napier grass, bajra or jwar; occasional small amounts of green weeds or wheat or barley bhusa. Succulent roughages, including green grasses and silage, are fed at the rate of 6 pounds daily for each 100 pounds of body weight. When fed, one pound of dry roughages, bhusa or dry hay, replaces 2½ pounds of succulent roughages.

Roughages are purchased from the Agronomy Department of the Institute at rates current in Allahabad City markets, less the difference in the cost of hauling to the dairy as compared to hauling to the city. This difference amounted to 3 pies a maund in 1938-39*.

Green fodder is sometimes chopped by a hand operated mechanical cutter, although usually it is harvested while sufficiently small to be palatable without cutting. In the case of fodder used for silage it is cut and put into the silo as received from the farm. The costs for the cutter, labour and electric power are added to the cost of the fodder to give the cost of silage. The shrinkage and loss involved in making silage is cared for by considering the maunds of silage actually fed to the animals and the cost of the fodder which is cut into the silos.

The concentrate mixture consisted at that time of wheat bran, 55 parts, mustard cake 32 parts, linseed cake 10 parts and mineral mixture 3 parts. The mineral mixture contained bone meal, common salt, air slaked lime and potassium iodide The amount of concentrate mixture fed is determined by the volume of milk and its fat content, the age and general condition of the cow and the stage of pregnancy.

Concentrate feeds are purchased largely in the open market, since a very small portion of those used are grown at the Institute. Occasional small quantities of gram only are purchased from the Agronomy Department at market rates. Grinding costs are included as part of the cost of the grain feeds.

The original costs of both roughages and concentrate feeds, therefore, are practically those current in the Allahabad City market and are for this reason quite high, as will be seen

Lights and Water :

Electrical current consumption involves lights in the milking barns and feed store, and the power used for cutting fodder and grinding grain. Since power is included in the charge made for fodder and concentrates, lights only are charged separately.

*Misra, S B. (1912). Farm Cost Accounts in the Agricultural Institute, Allahabad. Allahabad Farmer 16, 65.

All water used in the cattle yard is metered through the Institute water supply system. The milking cows and buffaloes and the floors of the milking barns are thoroughly washed twice each day. Drinking water is supplied at all times in one of the three milking barns and in all paddocks. Quantities of water are used also for washing the milk house and the utensils. The consumption of one day was arbitrarily divided on a unit basis as follows :—

Buffalo cows	...	...	... 1·20 units
Zebu cows	...	...	... 1·00 "
Female young stock		...	... 0·40 "
Bulls	...	...	... 0·20 "
Calves (under 6 months)		...	... 0·12 "

The consumption for the year divided by the total number of units gave 25 gallon per unit. The figure may seem somewhat small for the bulls, but they are kept outside and are not washed off regularly; it represents, therefore, only water used by them for drinking.

Labour and Supervision :

The cost of labour is distributed among milk stock, female young stock and bulls, according to the proportion of time spent on each by each man. Some workmen spend full time on the milk stock whereas others spend only a fraction of their time on this class of animals. Charges are made accordingly. Labour costs in the feed store are included in the costs of items handled through the store, such as fodder, concentrates and miscellaneous items.

Supervision is divided, in the accounts of the Institute, to distinguish between senior staff members, whose primary duty is teaching, and those persons employed fully for the supervision of the commercial work in the different departments. The former will be dealt with later. At this point supervision, therefore, refers to the latter type, including the cattle yard supervisors, milk tester, milk recorder and the veterinarian. To the total expenditure on these men is added one-half the salary of the head clerk in the office of the Department. The total obtained hereby is divided one-half for milk stock and one-half for bulls and female young stock. This amount, as is true of certain other figures, is then distributed by cow-months.

Equipment :

The cost of an item of equipment will determine whether it shall be included under this heading or under the next one, that is miscellaneous. If its cost is very low, say a few rupees only, it is considered a miscellaneous expense and is so classified, otherwise it is considered an item of equipment, is entered in the equipment inventory and is

depreciated each year. All repairs are made by the Institute workshop at cost, which includes labour, materials, supervision and the use of tools Repair charges for all equipment, whether placed in one category or another, are included under equipment repair expense.

Depreciation costs vary with the individual piece of equipment involved. The usual practice is to depreciate an item about 10 percent annually, however, so that its replacement cost is accumulated over a period of years, allowing for a new purchase.

Miscellaneous charges :

Items under this heading include rope, kerosene oil, soap, wire for repairs, posts for replacement, matches, brushes, cloth, etc. Such items are quickly consumed and are considered as supplies rather than equipment which should be depreciated.

Bull services :

The number of bulls maintained at the Institute is larger than would be ordinarily needed on a strictly commercial dairy farm. The principal reason for this is the intensive programme followed in the improving of the Red Sindhi zebus and the Murrah buffaloes and in the cross breeding work with the Jersey and Red Sindhi animals. It is for this reason that expenses on bulls are placed in a research account. This account is credited, however, for each service a bull performs. The amount to be charged is determined by assuming one bull can give an average of 120 services annually. The cost for maintaining one bull for one year, including feed, labour, miscellaneous charges and depreciation on the bull, is thence divided by 120. In the case of zebu bull the cost comes to Rs. 2-1-6·0 per service; for the buffalo bull it is Rs. 2-6-6·5. This charge is made for each service necessary for conception. The cost for service is consequently very high for poor breeders.

Depreciation on Cows :

During the time a heifer is included in the female young stock inventory, her capital value is increasing each year. From the time she is transferred to the milk stock inventory appreciation stops, because the expenses of maintaining her are thereafter charged against the milk she produces and the capital value is then depreciated. The rate for depreciation for cows raised at the Institute is 16·6 percent a year. Should an animal have been purchased, the price paid for her plus expenses incidental to bringing her to the Institute becomes the basis of depreciation. The rate on such animals will vary from 16·6 percent upwards, depending upon the age of the animal at the time of purchase. The amount of depreciation on a particular animal,

therefore, varies with the transfer or purchase cost and the rate of depreciation. When the inventory value of a cow has been reduced by this method to Re. 1/-, annual depreciation stops until that year when she is removed from the milking herd by death or sale. At that time the remaining Re. 1/- is charged. In the costs as figured in this study each such animal has been charged Re. 1/- annual depreciation even though she may have continued in the herd throughout the year of the study.

Apart from variations in the cost of raising an animal, which occur particularly if they are raised at different times or in different years when the general price levels are or the cost index for materials and services used in their rearing is different, the earlier a heifer gives birth to her first calf the lower will her capitalization be, hence the lower the amount of depreciation charged against her during the first few years of her milking life. Early maturity, therefore, has its economic implications.

Departmental Credits

Manure:

All manure removed from the barns and paddocks at the cattle yard is delivered to the Agronomy Department for use on the fields. For purposes of inter-departmental financial adjustments it is assumed that one ton (2240 lbs) was delivered each day from the entire herd. The rate was Rs. 2-8-0 a ton. Each mature animal unit in the herd, at this rate, produced 16·1 pounds of manure daily or 491 pounds monthly (30·5 days). This would amount to Rs. 6-9-1·2 a year. The value of manure for the buffalo cow representing a mature animal unit, therefore, would be Rs. 6-9-1·2, while that for a zebu or crossbred cow would be approximately 70 per cent of that or about Rs. 4-9-6·8, since such an animal has a body weight of about 700 pounds or 70 per cent of that a mature animal unit.

Claves:

No credit is ordinarily given for new born calves. A few are sold at a day or two of age at Rs. 2/- each, so it is felt that this amount might be credited to each cow for a calf, if any, produced during the year.

Non-Departmental or Commercial Debits.

Interest on Capital and Building Depreciation:

Entrepreners usually invest their money only where there is some assurance of a profit in the form of interest or dividends. If the returns from one investment are not as great as they think they can get elsewhere they are liable to recall their money and reinvest it. Furthermore, the firm in which the money is invested must pay the interest expected by the investor as the cost of using his money in

their business. This constitutes an expense that must be charged against the product being manufactured or otherwise handled. Rates vary. In a case such as ours, where no interest is actually paid, the rate to be used, to make the accounting comparable to a commercial firm, must be arbitrary. We have used 5 percent.

The capital value of a cow, as has been indicated above, is that cost at which she is transferred from the female young stock inventory to the milk stock inventory or at which she is purchased. Thereafter this figure is reduced by the amount of depreciation charged annually against her. The capital value of a building is determined similarly, that is, the cost of construction is the original value which is in turn reduced annually by the amount of the depreciation, *viz.*, 5 percent of its original cost. This assumes that the building will last 20 years, which is actually low in many cases.

Supervision :

The senior members of the staff of the Institute are employed primarily as teachers. As such their salaries are not charged in departmental accounts. Since they give a part of their attention and time to the operations discussed here, however, some charge may be made in order that the cost represents a commercial cost. An expense of Rs. 100/- a month was assumed to represent this type of supervision in this study, since commercial or private dairies are inclined to pay up to Rs. 150/- or so for their senior supervision. The amount used here is charged only to the cows in the milk stock. For the herd as a whole, therefore, this is equal to a much larger sum, since of the 138·84 mature animal units in the entire herd, 85·11 are zebu and buffalo cows. This means that the cost of this type of supervision for the entire herd would amount to about Rs. 163/- a month. This was ample at the wage rates prevailing in this part of the country during the period under consideration.

Calculations and Observations.

The cows are grouped according to their breed or breeding in the following tables. Table I gives the monthly number of cows ; days in milk ; pounds of milk produced during the period of the study ; daily milking average, or pounds of milk divided by the days in milk ; overall daily average, or pounds of milk divided by 366 which is the number of days in the year studied ; the pounds of fat produced and the calculated fat percentage. The first figure indicates the average number of cows in each group monthly, the last is calculated from the pounds of milk and the pounds of fat given and the remaining figures are averages for one cow in the respective group.

TABLE I

	Red Sindhi.	Jersey-Sindhi.	¼Jersey-Sindhi.	Murrah.
Monthly number of cows ...	30·40	20·75	4·91	21·16
Days in milk	261·1	301·9	295·5	276·8
Pounds of milk produced ..	3043·2	4501·3	4334·2	3682·4
Daily milking average ..	11·52	14·91	14·67	13·30
Over-all daily average.. ..	8·31	12·30	11·84	10·06
Pounds of fat produced ..	147·7	228·0	206·1	254·7
Fat percentage (calculated) ..	4·85	5·06	4·76	6·92

The monthly number of cows in the Institute herd varied from 30·40 in the Red Sindhi group to 4·91 in the ¼Jersey-Sindhi group. The number in this latter group was small because of the programme of crossbreeding that is followed at this Institute had been continued about six years prior to this study, or only long enough to make available a very few such animals in milk during this period. In a few years, however, as indicated by the fairly large number of Jersey-Sindhi cows, there should be a sufficiently large number of the ¼-bred cows to give data on which to make a valid comparison with the other groups. Apart from this group, the comparisons can be made freely, since there are sufficient numbers, and they are approximately of the same magnitude, to make this feasible.

The number of days in milk depends upon several factors, *viz.*, how soon after parturition a cow is expected to breed, how soon thereafter she actually conceives, how persistant she is as a milk producer or her persistency of lactation, her health and possible other factors. We attempt to breed all zebu cows so that they will have a 12 month calving interval in which they are milking about 300 days and are dry about 60 days. We attempt to breed the buffalo cows, having a longer gestation period of 305 days instead of the 283 of the zebu cows, so that their calving interval is as short as possible, allowing at least 60 days for a dry period within the interval. It is impossible to reduce the calving interval of either the buffalo or the zebu cows to less than 30 days in addition to the gestation. This means that calves cannot be expected more frequently than every 335 days for buffalo and 313 for the zebu. Allowing 60 days of this time as dry period, the minimum lactation period possible would be 275 days for the buffalo cow and 253 days for the zebu cow. Any cow or group of cows whose milking period or lactation falls below the minima may be considered as lacking persistency of lactation, except where conditions of health may interfere. This would be parti-

cularly true in those cases in which the calving interval was greater than the minima indicated.

We feel that a calving interval of 12 months is optimum for the zebu. Any zebu cow in the Institute herd, therefore, which milks consistently less than 300 days can quite definitely be said to be lacking in persistency of lactation, except, as has been indicated, for health influences. This study, however, covering only a calendar year, does not show persistency of lactation clearly if at all. In other words, the 246·1 days in milk during the period for the Red Sindhi cows is not the number of days in milk during a complete calving interval, but during this particular calendar year only. There are suggestions, however, in these data that this group of cows does lack persistency of lactation. Whereas the Red Sindhi group averaged only 246·1 days in milk, the Jersey-Sindhi and ¼ Jersey-Sindhi groups averaged 301·9 and 295·5 days respectively, or between 30 and 35 days more More important, than this, however, the number of days in milk for the Red Sindhi group is less than the number to be expected with the smallest possible calving interval, whereas the drying interval, which approximately indicates the calving interval, for this group is about 444·0 days *. The same indications are found in the Murrah group as well. These are not conclusions, however, to be drawn from these data, but suggestions are evident.

The pounds of milk produced by the zebus is significantly higher for the Jersey-Sindhi and ¼Jersey-Sindhi cows than for the Red Sindhi cows. This is indicated not only by the total production but by the daily milking and the daily over-all averages. Since the two crossbred groups were in milk a greater portion of the year than the Red Sindh group was, the higher over-all daily averages are even more to their credit. The Murrah cows also produced more milk than the Red Sindhi cows.

Details of the cost of each item involved in maintaining one cow of each of the four groups for the one year of the study are shown in Table II.

The items are classified and sub-totals are given to show the importance of as well as the variation in the different groups of costs. The cost per unit of each item is the same for each group, except for depreciation on the cows which is explained elsewhere, since they involve the same period of time. The amounts of succulent and dry roughages, as has already been explained, vary with the body weight of the consuming animal. This accounts for the greater cost for these items in the case of the Murrah group. The rate of concentrate feeding is on the basis of milk flow. The variation in the cost of this class of feed is of the same nature, therefore, as is the average yield of milk shown in Table I.

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* Warner J. N. (1942). Report of the Dept. of Animal Husbandry and Dairying. Allahabad Farmer. 16, 40.

Items in the next group of costs, *viz.*, lights, water, etc., are practically constant for each cow, whether belonging to one group or another. This has been explained above.

With the number of services increasing as the breeding efficiency of a cow decreases and with the cost for each service the same, the cost for bull services in the different groups of cows should reflect, in part at least, their breeding efficiency. Also a longer calving interval would give rise to fewer services in any one period of time for the buffaloes than for the zebus, assuming the number of services for each conception being the same. This possibly accounts for the smaller cost of this item for the Murrah group, although they may have required fewer services in order to conceive. The small number of animals in the $\frac{1}{4}$ Jersey-Sindhi group may explain the larger cost there, or it may have resulted from the fact that a much larger proportion of the group produced calves and were subsequently requiring services during the period. This latter is suggested later by the high income for calves for the $\frac{1}{4}$Jersey-Sindhi cows.

Depreciation varies with the value of the animals at the time they enter the milking herd. The costs of materials and services will influence the cost of raising a heifer to the time she produces her first calf. The age at which her first calf is born, or her age at maturity, determines the length of time materials and services must be expended on her before her first calving. These determine her inventory value on entering the milking herd, and therefore the basis of depreciation costs thereafter. Some of the Red Sindhi cows were originally purchased at prices about equal to or slightly greater than the inventory value of young animals transferred to the milk stock inventory in the same year. Depreciation rates on purchased animals are slightly higher than those on transferred animals, as has been mentioned. This causes higher costs for depreciation on purchased cows, but for fewer years.

The Jersey-Sindhi cows are daughters and the $\frac{1}{4}$Jersey-Sindhi cows are grand-daughters of certain of the Red Sindhi cows. The months during which materials and services were employed to raise them to first calving were usually different in each case. There were, however, a few cases where the same months were involved, that is, where those of each group are about the same age. The buffaloes are largely young animals and are late maturing, both facts giving rise to a higher depreciation cost. Inventory value on entering the heard is determined, therefore, for each cow by the cost of materials and services employed in raising her to maturity and the age at which she matures or her purchase price and the age at which she is purchased. The average depreciation cost per cow in any group will vary, in addition, with the proportion of old cows recently purrchased and not completely depreciated, the number of old cows valued at Re. 1/- and the average age of maturity.

Among the Red Sindhi cows were several valued and depreciated at Re. 1/-. This largely accounts for the average depreciation cost of this group being less than the ¼Jers ey-Sindhi group The Jersey-Sindhi group matured very early, accounting for their low average depreciation. The ¼Jersey-Sindhi group was not only a little slower or later maturing than the Jersey-Sindhi group, but also was raised when costs for the materials and services necessary were slightly greater. Their small number must also be taken into account as must the fact that they are all young, including no one cow whose value is Re. 1/-.

Departmental costs are made up of items of Table II so far discussed. These constitute the gross deparmental cost Other items of cost to be discussed later do not involve expenses which must be met by Department of Animal Husbandry and Dairying.

Several factors might contribute to the average calf value in the different groups. As the calving interval increases, the number of calves produced by a group of cows in any arbitrary period of time would decrease. This largely explains the difference in the calf value per cow in the different groups. Furthermore, the number of calves produced by a group of cows, as is true of the ¼Jersey-Sindhi cows, may be a result of the age of the cows In this case most of the individuals involved came into the herd as transfers from female young stock during the period of the study, and animals are only transferred when they produce a calf. This figure is high in this case as compared to the larger groups, for this reason. The total days from the completion of one lactation to the completion of the next can be calculated from a table (referred to above) already available for this herd covering nine of the 12 months of this study. This is shown to be about 444 days for the Red Sindhi cows, 419 for the Murrah cows, 367 for the ¼Jersey-Sindhi cows and 365 for the Jersey-Sindhi cows. This period is inversely related to the calf value in the respective groups, with one exception. That exception is the ¼Jersey-Sindhi group. Here there happened to be six calves born to seven cows in a group averaging only 4·91 cows monthly. This greater number of calves, in relation to the number of cows in the group, resulted in the income from calves for each cow being greater on an average than the value of one calf, that is Rs. 2-7-1·3 as compared to Rs. 2-0-0.

The net departmental cost is obtained by crediting the gross departmental cost with the value of the manure and the calf. It has been explained that credit is given herein for each calf born, whereas in practice no credit is given in cases where the calf is kept or where it dies, but only when it is sold within a few days. Calves are sold shortly after birth very rarely. A credit seems reasonable however, to cover the cost of at least that one service responsible for the conception producing the calf, if not to partly repay the expenses involved in maintaining a dry cow for 60 days or more.

It has been stated that the Institute is not a purely commercial concern and operates its accounts accordingly. To make our costs comparable with a commercial dairy it is necessary to add certain costs, not actually paid by the Department of Animal Husbandry and Dairying, to those now paid to give figures that would be comparable for a commercial dairy. Such costs are interest on the capital invested in the cows and the buildings, building depreciation and senior supervision. The last three are the same for each animal regardless of the group to which she might belong The first, however, is dependent upon the original cost or transfer value of the cow As was explained when discussing depreciation on the cows, the Red Sindhi group included a larger proportion of old cows with low inventory values. Interest on capital invested on cows indicates that the original purchase or transfer value of Red Sindhi cows was actually greater than that of any other group

The total commercial costs for the different groups shows that the Red Sindhi cows cost the least to maintain during 1940. These were followed by the Jersey-Sindhi, the ¼Jersey-Sindhi and Murrah cows in that order. It will be pointed out later, however, that the utility of the different cows as producers of milk or butterfat does not follow or is not necessarily indicated by this set of figures.

TABLE II

	Red Sindhi			Jersey Sindhi			¼ Jersey Sindhi.			Murrah.		
Succulent roughage ..	66	1	9 3	66	12	2 9	61	0	5·1	115	13	3·6
Dry roughage ..	4	14	4 1	4	5	0·8	3	11	9·3	5	4	2·7
Concentrates	56	1	10·7	84	15	2·2	82	5	8 6	66	2	10·5
Total feed ..	127	2	0·1	156	0	5·9	147	1	11 0	187	4	4·8
Lights	2	1	4·9	2	10	6·0	2	9	5·2	2	1	5·7
Water	4	11	3 8	4	12	0·1	4	10	6·6	5	11	9·9
Labour	16	5	11 3	16	5	9·7	15	6	1·9	16	5	10·6
Supervision and Clerical ..	5	9	8 2	5	9	7·6	5	8	2·8	5	9	6·8
Equipment Depreciation ..	1	12	3·8	1	12	3·4	1	[illegible]	4·1	1	12	2·6
Building and Equipment Repairs.	2	4	3·9	2	4	3·6	2	3	8·8	2	4	3·7
Miscellaneous Charges ..	7	4	6·8	7	4	8·4	7	2	10·5	7	4	7·2
Total of miscellaneous items.	40	1	6·7	40	11	2·8	40	5	3·9	41	1	10·5
Bull Service ..	4	1	1·6	3	10	11·9	4	3	2·5	3	1	2·1
Depreciation ..	37	2	11·8	33	5	10·7	46	5	6·6	47	14	4·0
Gross Departmental Cost	208	7	8·2	233	12	7·3	238	0	0·0	279	5	9 4
Manure	4	9	5 9	4	9	6·7	4	9	7·6	6	9	1·2
Calf	1	6	1·3	1	14	10 1	2	7	1·3	1	14	3·0
Net Departmental cost	202	8	1.0	227	4	[illegible]	230	15	3·1	270	14	5·2
Interest on Capital in animals.	15	3	11·5	11	4	0·0	13	8	6·4	14	3	7·0
in buildings ..	4	4	1·6	4	4	0·0	4	4	1·1	4	3	9·0
Building depreciation ..	4	4	1·6	4	4	0·0	4	4	1 1	4	3	9·0
Supervision ..	9	14	1·0	9	13	11·4	9	14	0·1	9	13	5·1
Total commercial items	33	10	3·7	29	9	11·4	31	14	8·7	32	8	6·1
Net commercial cost ..	236	2	4 7	256	14	1·9	262	13	11·8	303	6	11·3

Table III shows all costs, after some grouping, on the basis of each 100 pounds of milk produced by each of the four groups of cows. The grouping of costs in most cases involves those items that are constant for each cow regardless of the group into which she may be placed. Feed costs are lowest per 100 pounds of milk for the ¼Jersey-Sindhi cows and highest for the Murrah cows. This latter is to be expected with such high costs for succulent roughage, greater amounts having been fed them because of their much greater body weight. The smaller milk production of the Murrah group than the Jersey-Sindhi and the ¼Jersey-Sindhi groups would also account in part for this high figure. The cost of feed per 100 pounds of milk for the Red Sindhi cows is largely a result of the relatively high roughage costs resulting from their production being below either of the other three groups. The concentrate costs for 100 pounds of milk are almost the same for each group since concentrate feeds are fed on the basis of milk production, as has been explained.

The total for lights, water, labour, supervision, equipment depreciation, building and equipment repairs and miscellaneous charges varies inversely with the total milk production, that is this cost for the Jersey-Sindhi group is the least followed by the ¼Jersey-Sindhi, the Murrah and the Red Sindhi groups in increasing order.

Although in Table II the cost for bull services for each buffalo was the lowest of the four groups, in this case it is higher than the Jersey-Sindhi group. This results from the lower production of milk by the Murrah cows. Somewhat the same thing occured with the Red Sindhi as compared to the ¼Jersey-Sindhi group. The higher production of milk in the latter case reduced this cost for each unit of milk more than it was reduced by the production of the Red Sindhi cows.

Except for the buffalo cows, the value of the manure and calf per unit of milk is low for high milk production and high for low milk production. In the case of the buffaloes, the greater manure production, because of the greater body weight, accounts for the higher total for these two items per unit of milk. The difference between this figure for the Murrah and Red Sindhi groups is probably not so great as it would be if they had produced more nearly the same amounts of milk.

The net departmental cost for 100 pounds of milk is lowest when production is highest so far as the zebus are concerned. Whether this would also be true for different groups of buffaloes is not shown by the figures given. It is very likely, however, that it would be. Comparing the zebus and buffaloes, however, the cost of producing 100 pounds of milk is less for the former, than for the buffaloes, even for much lower producers.

The cost per 100 pounds of milk of interest, building-depreciation and senior supervision again follows inversely the milk production.

This would be expected when these costs are approximately the same for each cow, regardless of her milk production.

The net commercial cost for 100 pounds of milk is lowest for the Jersey-Sindhi cows. The other groups follow with increasing cost in the order $\frac{1}{4}$Jersey-Sindhi, Murrah and Red Sindhi cows. Table II showed that the Red Sindhi cow cost the least to maintain in production for one year, yet because of her comparatively low production her milk is more costly than that of the other cows. The difference between the net commercial costs for 100 pounds of milk from the Red Sindhi and the Jersey-Sindhi cows is Rs. 2-0-10·2 or approximately 26 percent of that of the Red Sindhi. The comparative utility of the Jersey-Sindhi, or cows equally as efficient in the production of milk, is obvious.

TABLE III

	Red Sindhi	Jersey-Sindhi	$\frac{1}{4}$Jersey-Sindhi	Murrah
Succulent roughage ..	2 2 9·1	1 7 8·8	1 6 6·3	3 2 4·0
Dry roughage ..	0 2 6·8	0 1 6·4	0 1 4·6	0 2 3·5
Concentrates ..	1 13 6·1	1 14 2·4	1 14 4·8	1 12 9·1
Total feed ..	4 2 10·0	3 7 5·6	3 6 3·7	5 1 4·6
Total of Miscellaneous items ..	1 5 1·0	0 14 5·6	0 14 10·7	1 1 10·3
Bull Service ..	0 2 1·7	0 1 3·7	0 1 6·6	0 1 4·0
Depreciation ..	1 3 6·6	0 11 10·3	1 1 1·3	1 4 9·7
Gross Departmental cost ..	6 13 7·3	5 3 1·2	5 7 10·3	7 9 4·6
Manure } Calf } ..	0 3 1·7	0 2 3·8	0 2 7·2	0 3 8·1
Net Departmental cost ..	6 10 5·6	5 0 9·4	5 5 3·1	7 5 8·5
Total Commercial items ..	1 1 8·3	0 10 6·3	0 11 9·4	0 14 1·6
Net Commercial cost ..	7 12 1·9	5 11 3·7	6 1 0·5	8 3 10·1

Table IV gives the costs, as grouped for Table III, of one pound of butter fat for each of the four groups of cows included in the study. The cost for feed per pound of fat varied inversely with the production of milk. The higher fat production of the Murrah cows offset their high roughage cost for the period sufficiently that the cost for this item per pound of fat is between that of the $\frac{1}{4}$Jersey-Sindhi and Red Sindhi groups, which is true of total production of milk, whereas for 100 pounds of milk, Table III, roughage cost for the Murrah cows was much higher than that of the other groups. Roughage costs for the two crossbred groups are just

two-thirds those for the Red Sindhi and Murrah groups. There is little difference in the total feed costs for one pound of fat between the Murrah and $\frac{1}{4}$Jersey-Sindhi groups, although the number of cases in the latter group may be too small to justify this comparison.

As would be expected, the total costs of lights, water, labour, supervision and clerical, equipment depreciation, building and equipment repairs and miscellaneous charges follows the production of fat in an inverse manner. The highest fat producers, the Murrah cows, show the smallest cost for each pound of fat for these items. Whereas the fat production of the Murrah cows was about 163 percent of that of the Red Sindhi cows, the cost of these items per pound of fat for the Red Sindhi cows was about 159 percent of that of the Murrah cows.

Bull service and depreciation costs for the different groups are highest for the Red Sindhi, per pound of fat, because theirs was the lowest fat production. The high fat production of the Jersey-Sindhi group reduced the cost of depreciation on a fat basis somewhat below that of the other zebu groups, in fact to just slightly over one-half of that of the Red Sindhi group.

The gross departmental cost is lowest per pound of fat for the Jersey-Sindhi and highest for the Red Sindhi group. This cost for the Murrah cows falls about midway between that of the Jersey-Sindhi and $\frac{1}{4}$Jersey-Sindhi groups, although a greater number in the latter case might change this relationship somewhat one way or the other. Had the average age of the $\frac{1}{4}$ Jersey-Sindhi cows been equal to that of the Jersey-Sindhi group, it is possible that their depreciation cost for each pound of fat would have been smaller, for there would have been some valued at Re. 1/- only, which would have lowered the average depreciation cost per cow.

The value of the manure and calf, per pound of fat, is greatest for the Red Sindhi cows and least for the Jersey Sindhi group, with the other two groups about the same and midway between the two named.

The higher value of manure and calf for the Red Sindhi group is not sufficient, however, to reduce the net departmental cost for the group appreciably. It remains the highest for the four groups. The Jersey-Sindhi group has the lowest net departmental cost, being only 727 percent of that of the Red Sindhi group. This cost for the Murrah and the $\frac{1}{4}$Jersey-Sindhi groups are much the same and are very close to that of the Jersey-Sindhi group.

The much-lower fat production by the Red Sindhi cows results in a higher total for costs of interest, building depreciation and senior supervision. The Murrah group has the lowest cost in this head because of the high fat production, but it is followed very closely by the Jersey-Sindhi group, with the cost for the $\frac{1}{4}$Jersey-Sindhi only slightly higher. These costs, fixed on a per head basis, also follow the fat production inversely.

The net commercial cost for one pound of butter fat is lowest for the Jersey-Sindhi and highest for the Red Sindhi cows. The cost for the Jersey-Sindhi is equal to nearly 70·4 percent of the cost for the Red Sindhi group. Again, as was true of the net commercial cost of 100 pounds of milk, the utility of the Jersey-Sindhi, or animals equally as efficient in the production of butter fat, is indicated.

TABLE IV

	Red Sindhi			Jersey-Sindhi.			½Jersey-			Murrah.		
Succulent roughage	0	7	1·9	0	4	8·2	0	4	8·8	0	7	3·4
Dry roughage	0	0	6·4	0	0	3·6	0	0	3·5	0	0	4·0
Concentrates	0	6	0·9	0	5	11·6	0	6	4·7	0	4	1·9
Total feed	0	13	9·2	0	10	11·4	0	11	5·0	0	11	9·3
Total miscellaneous items	0	4	4·2	0	2	10·3	0	3	1·6	0	2	6·9
Bull Service	0	0	5·3	0	0	3·1	0	0	3·9	0	0	2·3
Depreciation	0	4	0·3	0	2	4·1	0	3	7·2	0	3	0·1
Gross Departmental cost	1	6	7·0	1	0	4·9	1	2	5·7	1	1	6·6
Manure } Calf }	0	0	7·8	0	0	5·5	0	0	6·5	0	0	6·4
Net Departmental cost .	1	5	11·2	0	15	11·4	1	1	11·2	1	1	0·2
Total commercial items..	0	3	7·7	0	2	0·9	0	2	5·7	0	2	0·5
Net commercial cost ..	1	9	6·9	1	2	0·3	1	4	4·9	1	3	0·7

The costs that are considered in this study are expressed in percentages of the net commercial cost in Table V. These figures are applicable either for maintaining a cow for a year, for 100 pounds of milk or for one pound of fat. Some use may be made of such a table by other workers, provided it is remembered that they apply only to the conditions found in 1940 at Allahabad and for animals whose level of production is similar to that of the cows included in the present study. As a guide, however, to those interested in knowing roughly what portion of the total costs is represented by feed, for example, or any other item of expense, this table is included. It will be noted that all cost items total about 102·5 to 102·7 percent of the net commercial cost. The apparent error is accounted for by the credit for the value of the manure and calf which is also given.

TABLE V.

	Red Sindhi	Jersey-Sindhi.	¼Jersey-Sindhi.	Murrah.
Costs.				
Roughages	30·06	27·67	24·63	39·90
Concentrates	23·76	33·06	31·32	21·81
Light	0·88	1·03	0·98	0·68
Water	1·99	1·84	1·77	1·89
Labour	6·93	6·36	6·23	5·39
Supervision	2·37	2·18	2·09	1·84
Equipment depreciation ..	0·74	0·68	0·67	0·85
Equipment repairs .. .	0·96	0·88	0·84	0·74
Miscellaneous	3·08	2·83	2·73	2·40
Bull services	1·72	1·43	1·59	1·01
Depreciation on cows . .	15·74	12·98	17·63	15·78
Commercial costs	14·24	11·53	12·14	10·72
Credit.				
Manure and calf value	2·53	2·53	2 68	2·78

Prices have the characteristic of changing independently of the changes in the utility or producing efficiency of the cows or of the quality of the feeds. During the past two years the price of wheat bran, for example, has increased from Rs. 1-8-0 to Rs. 6-0-0 a maund in Allahabad; while at the same time its quality as a feed material for milk production has diminished as wheat is now mixed with other grains before milling. Price changes, when prices are used to show the comparative utility of different groups of cows, may so disturb such a c omparison, as is made here, after a few months that the value of the study disappears. This may happen to a small degree by changesin the quality of feed materials, but not nearly to the extent noted when the general price level varies as it has in this country in the past two years. A comparison of the utility of groups of cows as producers of milk or butter fat by the use of costs for materials and services holds, therefore, only for the period in which the comparison was actually made, or other periods when the same price relationships exist between all materials and services involved. Such price relationships may never occur again, or if so only rarely. Comparing the utility of different groups of cows as producers of milk and butter fat on the basis of the quantities of materials and services involved in a

particular period is a much more reliable method than the use of prices, but has shortcomings in that the food value of a unit of feed material might change from time to time. The amount of work done by the average workman employed during one period as compared to another may also vary. A comparison on the basis of food value, in a biological sense, and work done per hour, in a purely physical sense, would obviously be the most scientific basis of comparison. This would involve complicated techniques, however, that are not ordinarily feasible.

On the other hand, the units of feed, labour, and supervision, of both types considered in the present study, expended in raising an animal from birth to her first calving might be added, as depreciation is added here, to those units utilized in maintaining an animal for a period of time, in producing 100 pounds of milk or one pound of butter fat. That is, depreciation might be expressed not as a proportion of the capital cost in units of currency but as a proportion of the capital cost in units of feed, labour and/or superivsion consumed in producing or raising an animal. These may then be added to those utilized in maintaining an animal, for example, to show the expenditure in more realistic terms than is possible when using currency as the units as rupees are used here. Such a study, it is proposed, shall be made later.

In the hope that something might be added to the present study that would partly, at least, overcome the lack of reliability in a comparison of the four groups of cows studied herein when using prices. Table VI is given showing seers or succulent and dry roughages and of concentrate feeds utilized for maintaining one cow in each group during the year of the study, for the production of 100 pounds of milk and for the production of one pound of butter fat. It is recognized, however, that variations in the nutritive value of such feeds at different times and in the genetic ability of other animals to respond physiologically to the use of such feeds may limit their comparison. Since it seems to be a more fundamental comparison that involving prices it may have a place here.

There is little difference in the roughage consumed by the three zebu groups for, as was explained earlier, they have almost the same body weight. The roughage consumption of the Murrah cows was much higher, being almost twice that of the ¼Jersey-Sindhi cows which were young and therefore of relatively small body weight. The amounts of concentrates follow the total milk production, since this class of feed was allowed in proportion to the milk produced.

The roughage required for 100 pounds of milk varied from about 156 seers for the ¼Jersey-Sindhi cows to over twice that amount, or 341 seers, for the Murrah cows. There was little difference in this figure for the two crossbred groups. The difference between the Red Sindhi and Murrah cows was about 100 seers, the Red Sindhi

figure being the smaller. The consumption of concentrate feeds was nearly the same for all groups since this class of feed was allowed on the basis of milk production.

Although the consumption of roughages by the Murrah cows was very much greater for the year than any other group, the higher fat production of these cows reduced the consumption of roughage per pound of fat to practically the same as that of the Red Sindhi cows. The roughages consumed per pound of fat was practically the same for the two crossbred groups but a little less than two-thirds of that of the Red Sindhi and Murrah groups The consumption of concentrate feeds per pound of fat was practically the same for the three groups of zebus, but somewhat less for the Murrah cows.

The food value per seer of concentrate feeds is very much greater than that of a seer of roughages. The feeding practices followed in this herd were such that the quantities of feed materials varied with either the body weight or the milk production, but not the fat production. The heat energy value of milk varies more nearly as the fat content varies, for two reasons: firstly, the heat energy value of one gramme of digestible fat (nine Calories) is about $2\frac{1}{4}$ times as much as that of a gramme of digestible carbohydrate or of digestible protein, and secondly, the percentage of fat present in milk varies much more than that of the carbohydrates or proteins. The efficiency of conversion of food energy in the form of roughage and concentrate feed materials to the food energy in the form of milk is, therefore, more readily shown by the units of feed required for the production of one pound of fat than that required to maintain a producing animal for one year or for producing 100 pounds of milk. More particularly, the utility of the different groups of cows as producers of butter fat, and therefore, probably producers of food energy, is indicated by the respective quantities of concentrate feeds consumed per pound of fat. This may be noted by reference to the Red Sindhi and Murrah groups where the consumption of roughages is practically the same, whereas the Murrah group consumed only about two-thirds as much concentrate feed as the other group for each pound of fat produced.

This suggestion receives some support genetically in that the potential producing capacity of a cow and the fat percentage of her milk are independently inherited characters and the best means of expressing these characters in a particular case is in terms of a product of the two, *viz.*, the total pounds of fat. Obviously the greater the production of butter fat per unit of feed expended the greater the efficiency of food energy conversion. Very likely a more fundamental axiom could be stated thus : the greater the production of butter fat per unit of concentrate feed expended, where this class of feed is fed on the basis of milk or especially fat production, the greater the efficiency of food energy conversion.

The smaller amounts of roughage feeds required by the two crossbred groups than the Red Sindhi group, whereas the three groups require approximately the same amount of concentrate feeds for a pound of fat, shows that they are more efficient producers of fat, and probably food energy than the Red Sindhi cows. The small number of cases in the ¼Jersey-Sindhi group, however, may not justify this claim, although it appears doubtful that they are much less efficient than the Jersey-Sindhi group. The Red Sindhi cows, or cows of this level of production it would seem, are less efficient in the production of butter fat, and therefore probably food energy, than either the Jersey-Sindhi, the ¼Jersey-Sindhi or the Murrah cows. It might seem wise to consider establishing feeding practices for production, particularly so far as concentrate feeds are concerned, on the basis of fat production instead of milk production or body weight. Morrison's and other standards care for this quite well, but they have not been designed for the animals found in India, least of all the buffalo cow.

TABLE VI

	Red Sindhi	Jersey-Sindhi	¼Jersey Sindhi	Murrah
Quantities per cow.				
Succulent roughage ..	7031·0	7089·5	6606·0	12337·5
Dry roughage	188·6	167·3	137·6	209·3
Concentrates	1042·3	1688·6	1512·5	1265·6
Quantities per 100 pounds of milk.				
Succulent roughage ..	231·0	157·5	152·4	335·0
Dry roughage	6·2	3·7	3·2	5·7
Concentrates	34·2	37·5	34·9	34·4
Quantities per one pound of butter fat.				
Succulent roughage ..	47·6	31·1	32·1	48·4
Dry roughage	1·3	0·7	0·7	0·8
Concentrates	7·1	7·4	7·3	5·0

Discussion and Conclusions

The Red Sindhi cows milked fewer days during the calendar year 1940 than did the Jersey-Sindhi, ¼Jersey-Sindhi or Murrah cows. They produced the least milk and least butter fat and had the smallest daily milking average and the smallest over-all daily average milk production.

The highest producers of milk were the Jersey-Sindhi cows, followed by the ¼Jersey Sindhi and then the Murrah cows The highest producers of butter fat were the Murrah cows followed by the Jersey-Sindhi and then the ¼Jersey Sindhi cows. The Jersey-Sindhi cows had the highest daily milking average and the highest over all daily average milk production.

The calculated fat percentage was highest for the Murrah cows, followed by the Jersey-Sindhi, the Red Sindhi and the ¼Jersey-Sindhi cows in the order named.

The net departmental costs for maintaining one cow of each of the four groups for the year under study are approximately Rs. 202/-, Rs. 227/-, Rs. 231/- and Rs. 271/-, for the Red Sindhi, Jersey-Sindhi, ¼Jersey-Sindhi and Murrah groups respectively. The net commecial costs followed the same order with approximately Rs 236/-, Rs. 257/-, Rs. 263/- and Rs. 303/- per cow for the respective groups in the order named. The major item of expense for each group was feed, of which roughages was the largest for the Murrah and concentrates largest for the Jersey-Sindhi cows. Depreciation costs were smallest for the Jersey-Sindhi cows principally because of their earlier maturity. Likewise, interest on capital invested in the animals was lowest for this group.

The net departmental cost for 100 pounds of milk was Rs. 5-0-9.4, Rs 5-8-3.1, Rs. 6-10-5·6 and Rs. 7-5-8·5 for the Jersey-Sindhi, ¼Jersey-Sindhi, Red Sindhi, and Murrah groups respectively. The net commercial cost on this basis followed the same order with Rs 5-11-3.7, Rs. 6-1-0·5, Rs. 7-12-1·9 and Rs. 8-3-10·1 for the respective groups in the order named. Again these costs were largely feed, with the roughage cost highest for the Murrah group and concentrate cost highest, in this case, for the ¼Jersey-Sindhi group.

The net departmental cost for one pound of butter fat was Rs. 0-15-11·4, Rs. 1-1-0·2, Rs. 1-1-11·2 and Rs. 1-5-11·2 for the Jersey-Sindhi, Murrah, ¼Jersey-Sindhi and Red Sindhi groups respectively. The net commercial costs followed the same order with Rs. 1-2-0.3, Rs. 1-3-0·7, Rs. 1-4-4·9 and Rs 1-9-6·9 for the respective groups in the order named In this case roughage cost is highest for the Red Sindhi group, but the cost for this class of feed for the Murrah cows is practically the same, while for the two crossbred groups this cost is slightly less than two-thirds as high. The concentrate cost is highest

for the ¼Jersey-Sindhi group but is only slightly higher than that of the Red Sindhi group. The cost of this class of feed for the Murrah group is only about two-thirds that of the ¼Jersey-Sindhi and Red Sindhi groups. The costs for lights, water, etc., are just less than twice as high for the Red Sindhi as for the Jersey-Sindhi or Murrah groups; that for the ¼Jersey-Sindhi group is about midway between those extremes. This is also approximately true for the commercial costs.

Dairymen have too often made the mistake of concluding that a comparatively low maintenance cost of a producing animal over a period of time is evidence of economical utility. This is not altogether true of the animals and the period covered by the present study. The cost of maintaining a Red Sindhi cow for the year considered here was less than that for a cow of either of the other groups The cost of 100 pounds of milk from the Red Sindhi cow, however, is significantly above that for Jersey-Sindhi or ¼Jersey-Sindhi cows and only slightly less than that of a Murrah cow. Furthermore, the cost of maintaining a Murrah cow for the year considered was considerably higher than for either of the other groups, yet the cost of one pound of fat from her was considerably less than that of the Red Sindhi cow and slightly less than that of the ¼Jersey-Sindhi cow. The cost of maintaining a Jersey-Sindhi cow was about Rs. 20-12-0 greater than that of a Red Sindhi cow, but 100 pounds of her milk cost Rs. 2-0-10 less and one pound of her butter fat cost Re. 0-7-6 less than that of the Red Sindhi cow.

Roughage feeds were fed on the basis of body weight; consequently, the consumption during the period of the study was much greater for the Murrah group than for the others. This amount was nearly two times that consumed by the ¼Jersey-Sindhi and over one and-one-half times that for the Red Sindhi and Jersey-Sindhi groups. Because concentrate feeds were fed on the basis of the milk produced, the consumption of this class of feed follows the milk production, that is the Jersey-Sindhi group consumed the most, followed by the ¼Jersey-Sindhi, Murrah and Red Sindhi groups in a descending order.

The consumption of roughage feed for 100 pounds of milk by the Jersey-Sindhi and ¼Jersey-Sindhi groups was less than one-half that of the Murrah group. The Red Sindhi consumption was about midway between these extremes. The consumption of concentrate feed was practically the same for all groups per 100 pounds of milk because of the basis on which the amount of this class of feed to be fed was determined.

The relatively high consumption of roughage feed by the Murrah group during the period of the study or per 100 pounds of milk is not manifest on the basis of one pound of butter fat. In this case it is almost identical to that consumed by the Red Sindhi

group. The consumption of roughage by the Jersey-Sindhi and $\frac{1}{4}$Jersey-Sindhi groups is about two-thirds that of Murrah and Red Sindhi groups. The consumption of concentrate feed by the three zebu groups is almost the same; that of the Murrah group is only about two-thirds as high per pound of fat.

The production of butter fat, particularly in the case of the buffalo cow, might offer a more fundamental basis for determining the amount of concentrate feeds to be given a producing animal than the amount of milk produced. The amount of concentrate feed utilized for each pound of butter fat produced may serve as a simple approximation of the efficiency of converting food energy in the form of milk by a milking animal.

Should the market in which milk is sold pay more for quantities of milk, such as the fluid milk market, than for quantities of fat and therefore food value, the zebu is more economical as a milking animal since such an animal produces milk at a lower cost than does the buffalo. If, on the other hand, the market pays more for quantities of fat or for food value, such as the ghee or butter markets or cases in which a cow is kept to provide milk for family use alone, than for quantities of milk, the Jersey-Sindhi cow, or cows of her level of production, is slightly more economical than the Murrah cows included in the present study. These buffaloes, however, are much more economical than the other two zebu groups, *viz.*, the Red Sindhi and the $\frac{1}{4}$Jersey-Sindhi cows, particularly the Red Sindhi cow which is indigenous to India. The high efficiency of butter fat production by the Murrah cows as compared to that of the Red Sindhi cows suggests that the buffalo is generally to be preferred to the zebu for the ghee or butter market or as a family cow.

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"In India nearly two-thirds of the milk produced is converted into milk products by producers themselves before sale."—Report on the Marketing of Milk in India and Burma, 1941.

GE NETICS AND THE CATTLE PROBLEM OF INDIA.

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Introduction

The report of the 1940 cattle census (1) reveals that India (excluding Orissa and 21% of Indian States—figures for which are not available) now possesses 158,306,337 heads of cattle. Of these, the milk stock which comprises not only cows in lactation, but also cows that are dry or carrying calves, form about 32%. If it were possible to arrange the milk stock alone in a military formation, with their bellies touching so as to form a continuous row, that row would cover 10,000 miles or one and a quarter times the diameter of the earth !

The calculated world cattle figure is about 650,000,000 (2). This means that India alone contributes one fourth of that number. This gives us too many cattle per acre of cultivated land, so that, there is some justification for Masani's remark, "Like ourselves, our cattle too are far too many" (3). We do not see any positive danger in an even larger cattle population, provided the cattle are of the right kind and are able to "pay their keep". Unfortunately, our cattle are not always of such a category and in most cases do not always give sufficient returns in the shape of milk or work, for their keep. About 4,500,000 of our cattle (1) neither produce any milk or do any work. Economically, they are anything but useful ; only the inherent prejudices of our people against sending them to the butcher have kept them alive. Elsewhere, they would long ago have been sent to the slaughter house and eaten. In India alone of all the countries of the world, they are safe ! What is the result ? Not only do these useless cattle lower the net food available for distribution amongst the more productive of our livestock, but, being useless, also cause a total annual loss (on a conservative estimate of fifty rupees per annum per head for keep and management) of some 228,000,000 rupees—a sum that would have effectively dealt with the present suffering in Bengal or kept 10,000 average middle class Indian families above want for *nineteen* years! No doubt Dr. Higginbottom calls us "A nation ruined by its cattle" (4).

The total annual outturn of milk in India is about 6,400 million gallons (5). U. S. A. with only half our cattle strength, produces twice as much and Germany with only one-seventh of our cattle population, equals our annual milk output (3). The reason for this discrepancy between cattle strength and total outturn of milk in India

is in large measure due to the low average yield of our cows and to the presence of the useless cows that bring down the over-all average milk produced per cow.

Wright (6) has calculated the daily per head consumption of milk by the Indian people, on the basis of the total yearly output being 6,400 million gallons, to be 7 to 8 ozs. This figure represents only the quantity of milk available per head per day *if* it were possible to distribute equally the total produce and does not represent the quantity *actually* consumed by Indians per head per day. That would vary with the types of people Among the poorer classes, the daily per head consumption is not perhaps more than 5 oz. (6), whereas, there are a great many of our countrymen who probably have never tasted milk ever since they left their mothers' breasts (3)!

Wright's figures are alarming enough when we take into consideration the recommendations of the nutritionists (6) for a person living under Indian climatic conditions They recommend 15 oz. of milk and milk products per person per day. This clearly shows that as it is India's outturn of milk is not sufficient to meet the normal daily requirements of her people In recent years, due to the rise in our population (7), the milk available per person per day, has further dwindled, so that today, as revealed by the report of the Agricultural Marketing Advisor (5), it stands at such a low figure as 5·8oz. per head per day. This is a very serious situation indeed when we remember that Indians being mostly vegetarians, the only source of animal proteins for growth and development is from the milk and milk products they consume. What is the remedy ?

The four Alternatives Before us

If we want to check the further deterioration of our essential food supply and lay the foundation of a strong and healthy nation, the following four alternatives are open to us.

(1) Check the rapid rise in human population.

(2) Import foreign milk and milk products to offset our present deficiency.

(3) Take to eating beef.

(4) Develop the indigenous cattle industry and put it on a firm basis.

Alternatives (1) and (3) are out of the question due to the prevailing illiteracy and religious taboos. Illiteracy makes introduction of birth control measures impossible, whereas, the religious taboos make the eating of beef ordinarily unthinkable. As a rule, a Hindu would rather die than eat beef. The second alternative is not feasible because of the general poverty of the rural population, who will not be in a

position to buy the imported products. Furthermore, due to the prevailing prejudices against all tinned food materials, their popularisation is not so easy. The only course open to us at present and in which alone our future salvation lies, is to develop the indigenous cattle industry. To depend on outside sources, however admirable or cheap, for the essential and vital requirement in our diet, is to follow a policy of suicide, especially when that supply is likely to be interrupted or even totally stopped, as the present war has shown, at any time due to circumstances over which we have no control. Only an industry with roots deep in the native soil can thrive and be of any lasting benefit to be nation.

Importance of bullocks for work

The supplying of milk and milk products, though important enough, is not the only purpose for which we require our cattle. No less important is the work that we exact from the bullocks. The country, in spite of nearly two centuries of progressive rule, still follows methods of cultivation prevalent long before the times of the Gupta Emperors. This is not meant as a reflection on the present rule, but only shows the magnitude of the problem that faces us. Complete mechanisation of all agricultural pursuits does not seem possible at this stage, nor even at a very distant future. Nor will it perhaps be advisable to introduce machinery for farm work now, when the unemployment figures in this country are already high enough, without making some previous provision to receive the millions of farm labourers that would be thrown out of employment, if mechanisation of any extent is going to be practiced here. It looks therefore more than probable that we will be needing our bullocks for a long time to come to till our land and draw our carts.

Simultaneous Improvement of Draft and Milk Qualities – Essential

We have at present, more distinct and uniform draft than milch breeds of cattle. In fact, in India, breeding for draft had a more ancient beginning than breeding for milk. In spite of this initial advantage, breeding work for both draft and milk has been interrupted, off and on, due to the successive conquests of this country by alien nations and due to the consequent confusion that followed in the wake of such conquests. Any planned breeding programme therefore, must aim not only at increasing the productivity of the indigenous cattle, but also at improving the quality of the draft breeds.

Viceroy's Interest in the Cattle Problem of this Country

The question of cattle improvement has in recent years come to the fore, mainly due to the efforts and keen interest exhibited by

His Excellency, Lord Linlithgow in the cattle problem of this country. A beginning has already been made in the scientific improvement of our cattle. The policy adopted at present is one of castration of the inferior stock and grading up of scrub cows by improved and/or pedigreed bulls. With a view to increase the number of such bulls available for distribution in the villages, a record is being maintained of high grade cows and all the calves born to them. Breed characteristics of some of the more important Indian breeds of cattle have been defined and herd books opened for them. The latter would only help in bringing about an improvement of the higher grade animals. As far as the inferior stock that form the bulk of the cattle population in this country is concerned, the policy of castration of the inferior bulls and grading up by approved ones seems to be the only method of improvement available at present to raise their general standard. Therefore, we will confine our attention only to this method of improvement, as it touches the great majority of the cattle and any improvement brought in them *only* is likely to have telling effects on the increase in the general level of cattle standard. There are many drawbacks in depending on the method of grading up *alone* for improvement of the inferior stock. They are :—

(1) Scarcity of the Approved Bulls Available for Distribution

The Royal Commission calculated that an annual supply of some 200,000 bulls is needed to meet the needs for improving the cattle population in this country. The number of bulls issued annually from Government and private farms has more than doubled since the time of the Royal Commission; even then, the total number issued for stud work still falls far short of the number actually needed by India. Wright (6) found 10,000 approved bulls at stud in eight of the Provinces in India. Even assuming that this number has increased FOUR TIMES, the number still falls far short of the number needed by India. Assuming that the present rate of bull replacement will be maintained in the future, it will take quite a long time before we can completely replace all the scrub bulls by approved ones. That means, till that remote time, we will have to use always a percentage of inferior bulls for stud work. At this rate, cattle improvement may well take thousands of years and even then there is no guarantee of lasting progress being achieved

(2) Pedigree not Always a "Hall Mark" of True Breeding Worth

Even when a bull comes from a pedigreed stock and shows ideal body conformation, there is no guarantee that he would always fulfil his "great expectations". In fact, instances are not lacking where a bull of exceptional appearance and pedigree has lowered the milk

production of its daughters over that of their dams. A Red Sindhi bull reported by Schneider at the Agricultural Institute, Allahabad, greatly affected the Institute's dairy herd by reducing the output of milk of its daughters over that of their dams A similar instance is graphically illustrated by a chart at the Kankrej Breeding Farm, Surat, in which after three generations of progress the milk production was decidedly decreased in the fourth generation by using a bull which reduced the yield of all its daughters. This clearly shows that body conformation and pedigree will only serve as *guides* and not as absolute factors that would help us in assessing the true breeding value of a bull. The true breeding value of a bull lies in its actual performance as shown by the increase or decrease in milk yield of its daughters over that of their dams or increase or decrease in the draft qualities of its sons.

(3) Artificial Insemination and how it can Offset the Present Deficiency in the number of Approved Bulls

It is true that when once a bull has proved its worth, it could be more extensively used by having recourse to artificial insemination; so that, from a single ejaculate at least 10 to 15 cows might be served. But local prejudice fundamentally due to ignorance, against this practice, as also the lack of technical staff trained and available for such work, makes artificial insemination impracticable on a large scale in India for a long time to come. The following figures will speak for themselves.

In 1939, at the Agricultural Institute, Allahabad, 48 cows brought in mostly by the surrounding villagers were served. Some of these cows were brought from as far as ten to fifteen miles which shows the importance which the villagers attach to the use of superior bulls to father the calves born to their cows. Yet, in 1941 when artificial method was substituted in place of the natural one, to prevent chances of infection of the bull by unknown cows, the number of services that year dropped to 4. In 1942, it was 7 and in this year up to the end of November, 6.

(4) Time taken to affect Improvement even when all the Bulls used are "Proved"

Granting that all the bulls used are "proved" ones and that there are no bulls used that are inferior or of doubtful transmitting abilities, and assuming for a moment that milk yield is a character depending on only a *single dominant* gene, and rigorous selection is made for it in each of the generations that would follow, it would take *ten* generations or at least *thirty to fifty* years to bring the percentage of high producers from the initial 25 per cent. to 81 per cent. Selection, besides, makes rapid progress in the beginning, but progress becomes

slower in later generations due to the difficulty of distinguishing between the homozygous and heterogyous individuals, till finally as undesired trait becomes rarer and rarer and reaches the normal figure of mutation rate for that gene, a balance will be reached between selection pressure on one side and mutation pressure on the other, when selection will have no effect. In practical animal breeding work, if the breeder is starting with a small percentage of desirable individuals he cannot usually carry out any intensive culling amongst his female stock. He will be forced to retain a percentage of animals that do not conform to his ideal just to replenish his herd. That means a proportionate increase in the time taken to reach the goal that he has set for himself. We made above the assumption that milk yield is influenced by only a single dominant gene. Actually, however, milk yield is influenced by many genes, some probably dominant, others semi-dominant and still others recessive, situated in different chromosomes The chances of "fixing" such a heterogenous character may better be imagined than explained.

Necessity of a New Approach to the Problem

What then should be the basis of cattle improvement, if grading with superior bulls *alone* is not sufficient? As milk yield and draft ability are physiological characters that cannot be *seen* but only gauged from the actual production records (which means one will have to wait till the animals reach production age) a method must be evolved that would give us the information we seek at an early date It should at the same time be simple enough to be understood even by an illiterate farmer. This method should not radically differ from the method which the villager is in the habit of using at present. In other words, what we are seeking is to put the visual observation method so extensively used by all breeders on a firm scientific foundation. Is it possible to evolve such a method that would correctly tell us the future performance of an animal through an early observation of its external characteristics? That is the question which we propose to answer in this paper.

On theoretical grounds, we are led to believe that such a method is *possible*. For this purpose, a properly planned and controlled experiment will have to be undertaken, lasting for at least two generations, which in practice means five to ten years The expenses involved in such an experiment makes it outside the reach of private individuals or even Institutes, without Government co-operation and help. The investigation in the main would be genetical and would be conducted under the supervision of a qualified geneticist.

Principles Underlying the Suggested Experiment

The main principles underlying the suggested experiment is to find out *linkage*, if any, between the physiological characters

that cannot be seen on the one hand and body characters that can be seen on the other. In other words to find out the *chromosomes* of the physiological characters. The body characters will then act as our "gestapo agents" or "markers" who would give us information whether a certain physiological character is present in the animal or not. Once we have established a definite linkage between the two, then selection work would become easier.

(1) We need not have to wait till the animal reaches production age for culling. For example, if we find that straight horns, straight back and black body colour are associated with high yield, we have only to select animals which show these characters and reject the rest, to get cows of higher yields.

(2) Even a farmer with no knowledge of the present methods in selecting herd sires, could go ahead with his selection of herd sires with equal efficiency and with equal certainty of getting the desired results. In fact at present breeders both for draft and milk are in the habit of selecting certain body traits or conformation in animals as indicative of their probable future performance. For instance, a tight sheath, thin dewlap, broad nostrils and so on, are preferred in draft cattle. A hanging sheath, loose and hanging dewlap, thin and pliable skin and so on, in milk cattle. The present experiment would verify the truth, if any, of the above beliefs and put them on a sound scientific basis.

(3) Results obtained by this experiment, if satisfactory, would make it possible to introduce the visual test on a larger scale and its popularisation amongst the farmers should not be difficult as it is the very method which he is following at present, but put in a new guise.

(4) Once all the cattle breeders take to this visual method, general cattle improvement would proceed at a greater pace than at present.

(5) Also the time taken to achieve that improvement, unlike the time taken if the present method alone is followed, would also be shorter; this is because, selection work would now be undertaken by all cattle breeders who have at present no access to improved bulls.

(6) This experiment would prove the validity or otherwise of enforcing a rigid standard of breed characteristics in admitting the higher grade animals for registration, by finding the soundness or hollowness of certain characteristics which may be called as mere "fancy points," but now included in breed definitions. It would tell us whether we should pay any attention at all to these fancy points. For example, two or three Murrah buffaloes belonging to the Agricultural Institute, Allahabad, were refused registration, simply because their horns are not typical Murrah as laid down in the breed definition. Now at this stage, one may very well ask, "Are we trying to improve horns or milk?" If it is the milk that we desire and not horns, the less attention we paid to the horns the better. More so in the initial

stages, when we are trying to build up a stock of high producers from a otherwise heterogenous lot. For, genetically, milk yield and draft ability being more complex characters, they are more difficult to "fix" than the genetically simple, shape and size of the horns. Once we have a stock of high grades in sufficent numbers, then it should not be difficult to "insert" any fancy point that we particularly like or desire in the genetical constitution of a breed. Besides, in the absence of any concrete evidence of any proved linkage between the visible and invisible genes (here for instance the shape of the horns and milk yield), enforcement of an arbitrary fancy point, may actually hamper selection for the desirable invisible gene or genes (milk yield here), especially, *if the chromosomes of the visible and invisible genes happen to be different and the former in addition happen to contain gene or genes having bad non-additive effects on the expression of the invisible gene or genes* For example, let us assume that the chromosome containing the gene or genes that produce the typical Murrah horns contains no genes for milk and that it contains certain gene or genes that definitely retard milk production. By selecting for Murrah horns one would be unconsciously selecting for the negative genes of milk production. The reason why this assumed negative influence is not always *felt*, may be sought in the phenomenon of "crossing over" which gives plenty of scope for the Murrah chromosome to replace its negative modifiers by their normal allels. That is also the reason why we sometimes find animals that are typical Murrah as regards horns, but have reduced milk yield and sometimes animals that are not typical Murrah as regards their horns, and yet are good producers. *Our aim should be to select the good producers and see that their progeny is not lost.*

(7) Detection of harmful genes associated with the enforced breed characteristics becomes possible.

(8) The experiment can be so devised that it would at the same time give us information about the chromosomes of milk and draft.

(9) It would at the same time provide a *definite answer* to that much discussed problem, namely the possibility of evolving a dual purpose animal for India, an animal which in the words of Higginbottom would, " Not only fill the pail, but pull the plough ".

(10) The experiment would test the probable influence of the sex chromosomes on milk yield and draft ability.

The method advocated here can not only be used in cattle, but in the case of all domesticated mammals, where similar information is being sought. It can for instance be used with profit in goats and sheep.

The suggested experiment is discussed in detail below.

Initial "Spade Work" Essential

Before we proceed any further with the contemplated experiment it is necessary to clear one point namely, that we must have clear measures of the two qualities, milk yield and draft ability, which we propose to study. One can measure milk yield by finding the total amount of milk given by an animal in a lactation or if more than one lactation records are available, by finding their average. Correction factors for the age of the cow, duration of dry period, duration of service period, season of calving, difference in fat percentage and so on are now available (Refer to works of Sanders (13) and others and in India that of Sukhatme (unpublished, but soon to be published) so that it will not be difficult to standardise the yields of the cows for the purpose of comparison. But how can one measure draft? That is a difficult problem and no work of any kind on cattle is available for the purpose of evaluating the true draft quality of an animal. Fortunately, experiments are underway which are largely financed by the Imperial Council of Agricultural Research, to find out among other things, and accurate, workable, quantitative test for draft. For the sake of this experiment we assume that such a draft test is already available.

Next Step

Having first cleared the position regarding what tests for milk yield and draft ability we are going to follow, the next step is to plan the scheme of matings.

The animals selected for the initial cross, must differ from each other *in as many contrasting features as possible.* This is important, as it would provide us with a number of "markers", from which, we will be able to follow the distribution of the qualities of the two parents, in the succeeding generations. If for instance, we use two animals that are identical in appearance, colour and size, for the first cross, then it becomes very difficult, even impossible to ascertain whether a given character in the F_2 or F_3 progeny comes from the original maternal or paternal stock. If for instance, our animals used in the first cross are both white, we will not be able to say, whether or not a certain white animal in F_2 or F_3 has received its white colour from the maternal or paternal stock.

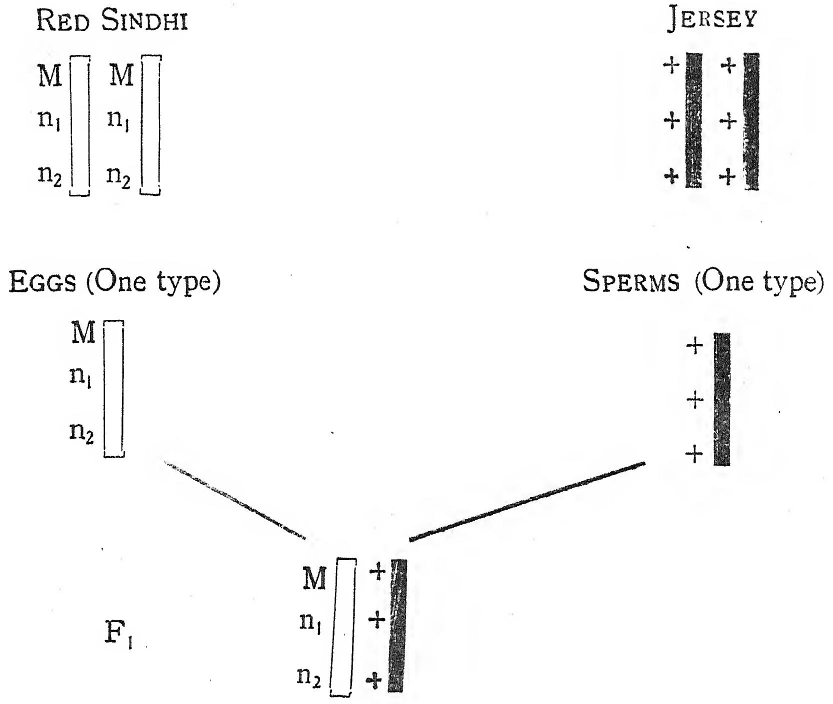
On the other hand, if we use animals that differ from each other in a number of contrasting features, then by simply looking at the F_2 or F_3 progeny, we can say which of its character it has inherited from which of its original parent. Not only that, we will also be able to say whether or not these descendents contain one or two of a given original maternal or paternal chromosome. A humped animal, descended from a Jersey-Sindhi cross, must have the "hump" gene in double dose, since "hump" is recessive and requires two

doses to make its appearance. Since " hump " originally came from the Red Sindhi parent, the animal in question will also have two original chromosomes of Red Sindhi containing the character " hump ". A straight backed animal descended from the same cross, on the other hand, may have one or two of the original chromosome of Jersey bearing that character, as " Straight back " is dominant and can show even when present in single dose.

Secondly, the animals used for the initial cross must possess *only one of the two qualities that are being tested* (Draft and milk here) and must belong to *distinct breeds* that in turn, show only one of these two qualities The reason is, if we use for the initial cross animals possessing identical quality, then, it will be very difficult to determine in the succeeding generations whether an increase or decrease in milk yield or draft ability that we might obtain, is due to the chromosome complex received from the original paternal or maternal breed.

For example, at the Agricultural Institute, Allahabad, when Red Sindhi cows averaging 1,900 lbs. were crossed to a Jersey Bull, their daughters gave on an average 4,600 lbs. This is an increase of 2,700 lbs. or 142%. Here, it cannot definitely be said that the 142% increase that we get, is *solely* due to the introduction of foreign genes, as *both Red Sindhi and Jersey are milk breeds.* It is true that the Red Sindhi cows actually used are poor milkers as compared with the average performance of the breed, but it does not follow from that *genetically* too they are " poor ". It can be argued that their low production is due to (1) the retarding influence of the recessive negative modifiers unconsciously selected along with the selection for positive modifiers when selection is made. In fact, such accumulation of negative modifiers becomes all the more probable, if both the positive and negative modifiers are located on the *same chromosome.* Their daughters, on the other hand, suffer from no such handicaps, as they will have facing their chromosomes containing the negative modifiers, like chromosomes that probably will contain no such modifiers or contain their wild alleles. If the foreign chromosomes also contain identical negative modifiers as the Red Sindhi chromosomes, then we should not have obtained my increase in the milk yield amongst the daughters, as the retarding influence of these modifiers would have been felt. The very fact that the daughters surpass their dams' records clearly shows that the foreign chromosomes do not contain these *very* recessive negative modifiers. They on the other hand may contain different ones not found in the Red Sindhi stock. Hence the retarding influence of one is nullified by the wild alleles coming from the other stock. Let M stands for the dominant gene or genes for milk production situated on a certain chromosome and n_1 and n_2 the two recessive negative modifiers linked to M. Let the signs + + +

stand for the normal alleles of these genes found in the like foreign chromosome. The constitution of the F_1 is given below :—



As n_1 and n_2 have their normal alleles facing them in F_1 individuals, they will not be able to show their effects, since they are recessive and can only show themselves when present in two doses. M therefore will be able to show its effect to its fullest capacity.

(2) It can be argued that the resulting 142% increase is due to the additive effects of *similar* recessives or *different* dominant positive modifiers that increase milk yield and coming from both the Jersey and Sindhi breeds.

(3) Due to the non-additive effects of genes coming from Jersey and Red Sindhi breeds

(4) Due to a combination of any two or more reasons ennumerated above.

The correct solution is problematical.

If on the other hand, one of the breeds used is *not a milk one*, and if we find a similar increase in the yield of daughters then we will have no difficulty in determining to which of the chromosomes

foreign or indigenous, this induced increase is largely due. That is the reason why for the initial crossing the animals used must not only differ in as many contrasting features as possible, but at the same time they must show and belong to distinct breeds possessing either draft or milk quality. The breeds that we personally prefer are Amrit Mahal and Jersey. Any two other breeds that fulfill the conditions mentioned above may do as well.

Scheme Of Matings

Jersey male is crossed with 50 to 60 Amrit Mahal cows *Known for their low productivity.* The number 50 to 60 is used in order to ensure that a sufficient number of F_1 animals of strong constitution will be available for further crossings. Not only that, we will be able to get information regarding the behaviour of the first generation animals regarding the two qualities, draft ability and milk yield, that we are proposing to test.

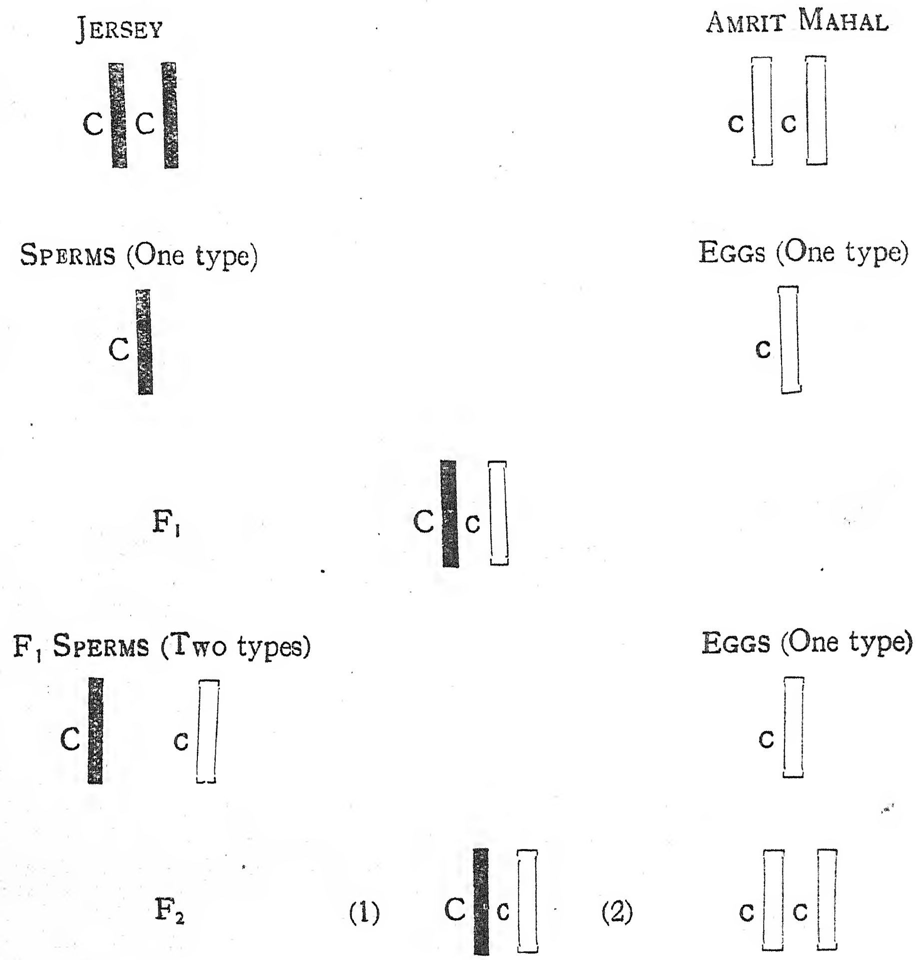
Nature Of The Second Generation Crosses

For further matings, *six* only of the F_1 *males* are used. They must be animals with exceptionally strong constitution. They are crossed to three to four hundred Amrit Mahal cows previously *tested for draft* and having *poor* milk records. The resulting F_2 animals are *all* tested ; males for draft only, females both for draft and milk yield. According to the combinations of Amrit Mahal and Jersey characters they show they are classified into a number of groups and record regarding draft and milk of each group entered therein. Suppose a, b, c and d are four recessive visible characters found in Amrit Mahal breed. The corresponding characters found in the Jersey stock will be represented by A, B, C and D. The different possible groups, on the assumption that there is no linkage between any two of the considered recessives are given in Table I.

Why F_1 Males are preferred for further matings

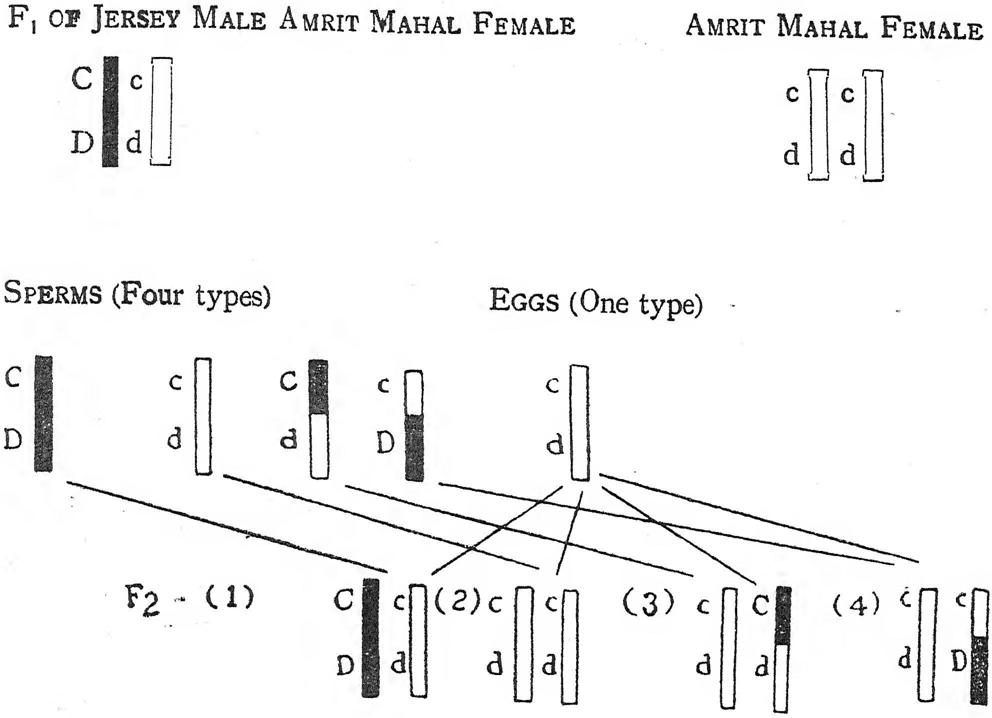
The nature of our experiment requires that the "markers" we use are reliable *i.e.*, give us information that is above suspicion. For instance, if we find one of our markers reappearing in the F_2 or F_3, we must be able to say that the whole chromosome which it represent or the whole series of linked genes with which it is associated, is there. Thus suppose the marker in question is crooked horns (C). It comes from the Jersey parent. The following shows the distribution of this

character and the groups of linked genes associated with in the first two generations



(1) F_2 individuals will have crooked horns and since crooked horns originally comes from the Jersey parent, we can say that these individuals have received the whole chromosome containing "Crooked" its Jersey ancestor. If now along with crooked horns, there are certain genes influencing milk yield, then "Crooked" individuals must also show either an increase or decrease in milk yield, depending on the positive or negative influence of the genes. This of course assumes that there is no crossing over between the "Crooked" and "straight" chromosomes in F_1 and that the genes influencing milk yield contained

along with "crooked" are dominant. If on the other hand, crossing over between "Crooked" and "straight" chromosomes in F_1 is there, then on the assumption that there is a single break and interchange, the number of F_1 gametes and F_2 individuals possible are given below :—



The number of (3) and (4) types of individuals will depend on the percentage of crossing over. As one can see from the above diagram, whenever C appears in an F_2 or F_3 individual, it will not be possible now to say with certainty, whether the whole or only a part of the original Jersey chromosome is there or not. In fact, it is quite possible to have an individual which would contain only that very small piece of the chromosome in which "Crooked" gene is located, with the rest made up of a proportionate piece coming from the like chromosome of the Amrit Mahal breed. What then will be the position of our markers, if along with them is present an invisible gene say D, affecting milk yield or draft ability ? The number of F_1 gametes and F_2 individuals possible on the assumption that only a single break and interchange takes place between "Crooked" and "straight" chromosomes in F_1, is shown also in the above diagram.

The marker C employed by us now is useless, as in (3) and (4) type individuals, it will not tell us whether the invisible gene D is there or not. Therefore, our marker becomes unreliable and the whole scheme of experiment gets upset. If on the contrary, there is *no* crossing over, the unexpected F_1 gametes and F_2 individuals will not be there. Such a thing is possible, if we use the F_1 *males* for further crossing and *not possible*, if we use the F_1 *females*. All the relevent data on the subject, in all genetically worked out animals show that crossing over is present in the homogametic sex (Female in the case of Drosophila and Mammals; males in the case of Moths and Birds) and not present in the heterogametic sex (Female in the case of Moths and Birds; male in the case of Drosophila and Mammals). In cattle too, the possibility is that, there will not be any crossing over in the heterogametic sex, *i. e.* male, and hence our preference for the F_1 males.

Influence of Sex Chromosomes on Draft Ability and Milk Yield

In the above experiment, all F_1 males receive their chromosome from the Jersey parent and their X from the Amrit Mahal parent. Y has been shown to possess few or no genes at all (exception certain fish called Lebistes) and therefore, any gene found on X of males whether it is dominant or recessive, will be able to show even when present in single dose. In fact, the question of dominance or recessivity does not arise in the case of sex linked genes in males having the XY chromosome complex. If the draft gene or genes are sex-linked, then all the F_1 males must turn out to be good draft. This however has not been found to be the case and therefore, one may conclude that possibly the draft gene or genes are not sex-linked, but are probably located on the autosomes. This point can further be verified by testing F_1 females, who also like the F_1 males have a single Amrit Mahal X chromosome.

Secondly, since we are using F_1 males for further matings, the F_2 females that we would get will be of two types (as there is no crossing over). Half would be exactly like the F_1 females as far as their X chromosomes are concerned (One X from Jersey and the other from Amrit Mahal) and the other half, like the Amrit Mahal. If we find on testing that the latter are good milkers, then we can safely exclude the influence of X chromosome on milk yield If on the contrary, we find that they are poor milkers, then it would lend support to the contention of certain authors especially Smith (1937), that some at any rate of the genes influencing milk yield, are sex linked

The actual conclusion to be drawn regarding what characters or what combination of characters will have to be selected for getting either draft or milch animals or both, will largely depend on the actual results obtained in F_2, when the suggested experiment is carried out.

To give a rough idea as to how we will proceed to interpret the F_2 results, the following example is given:—

TABLE I

Group		Draft	Milk
$\frac{aBCD}{abcd}$	...	−	+
$\frac{abCD}{abcd}$	...	+	+
$\frac{abcD}{abcd}$	...	+	−
$\frac{AbcD}{abcd}$	...	−	−
$\frac{ABcd}{abcd}$	...	−	−
$\frac{AbCD}{abcd}$	...	−	+
$\frac{abcd}{abcd}$	...	+	−
$\frac{ABCD}{abcd}$	...	−	+

We notice from the above table that distinct draft qualities appear *only* whenever there is a combination of a and b genes. Does that not show *since crossing over is absent*, that these genes have linked to them other genes that are responsible for the production of draft ability? In the same way, we notice that milk traits are only shown whenever there is a combination of C and D genes, which again would indicate that linked to C and D are certain genes tha' are essential for higher milk production. As it is shown to be possible in this example to have both a and b as well as C and D at the same time in the same animal, it further indicates that it is possible also to evolve a dual purpose animal.

How the work of selection will now become easy would be obvious. If only draft quality is wanted, select for a and b. If only milk quality is desired, select only for C and D. If on the contrary a dual purpose animal is the goal, select for both a and b, and C and D at the same time.

If all the farmers and breeders are encouraged to base their future selection on these lines, the general rate of cattle improvement not only will be hastened many times, but also, within a shorter period, we will be able to bring about a revolution in the general level of cattle standard in this country. The huge expenses now involved in waiting till the animal comes of production age and shows its transmitting abilities, if any, will now be curtailed and that sum made available for some other of the nation building activities.

ACKNOWLEDGMENTS.

The author is indebted to Dr. T. W. Millen for permission to make use of the Institute records and for many suggestions To James N. Warner, his thanks are due for having spared time to go carefully through the manuscript and for making numerous corrections and suggestions.

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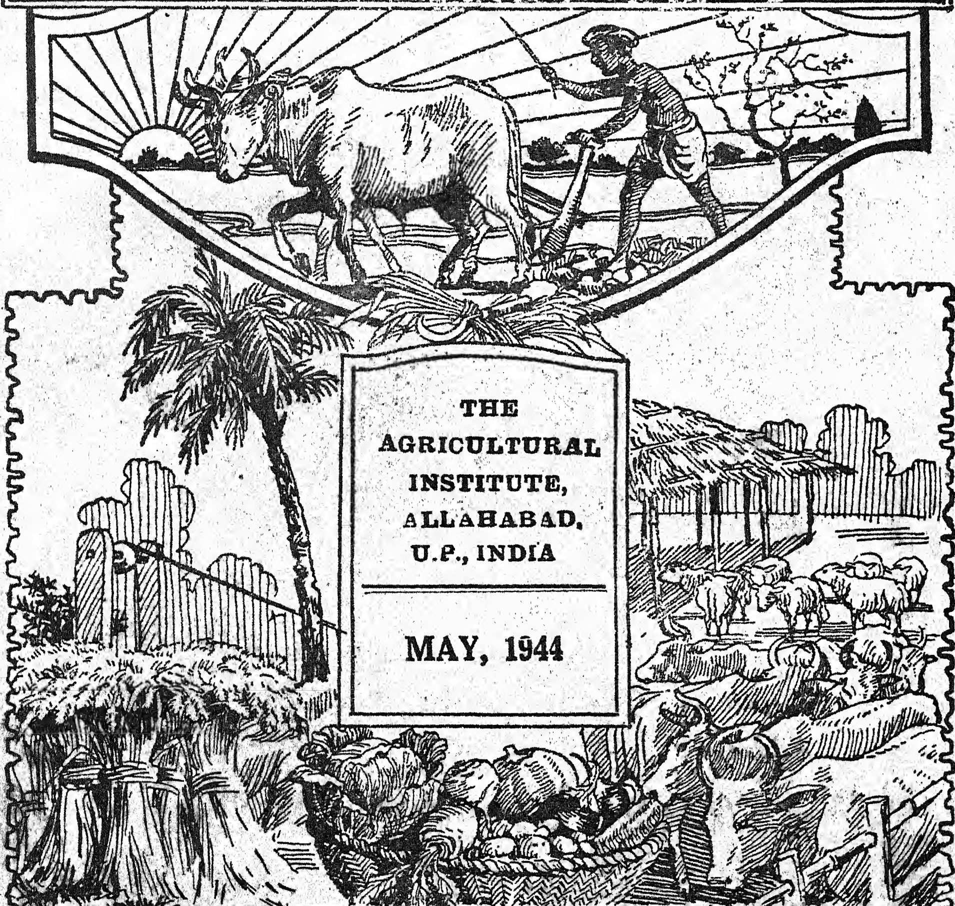

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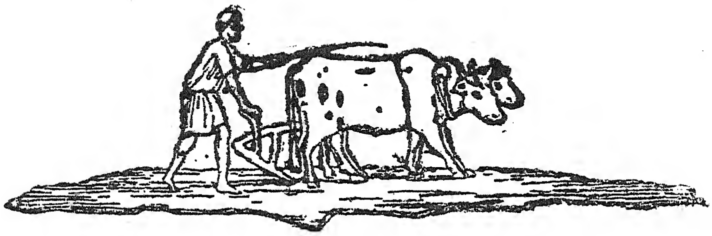

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CONVOCATION ADDRESS*

By

C. Maya Das

Director of Agriculture, United Provinces

I am grateful to the Institute and especially to Mrs. Higginbottom for giving me this opportunity of addressing the convocation of the Home Making Department. I have during my 27 years of service been deeply interested in the betterment of the economic condition of some 80 per cent. of our population and in my constant contact with the cultivator have often thought what a difference it would make to his prosperity if our educated women could be persuaded to improve the conditions under which the villager lives.

When I first heard of the Home Making Department here, I was glad that someone had started the ball rolling. In the 7 or 8 years of its existence the Department appears to have made very satisfactory progress towards achieving the end in view. This end or object, as you know, is two-fold :—

*This address was delivered at the Convocation of the Home-Making Department of the Allahabad Agricultural Institute, on the 3rd April, 1944.

(i) to impart the necessary training to young women in caring for and improving their own homes; and (ii) to train social service workers who could instruct students in the art of home making.

There are to-day some 188 million women in India of whom some 80 per cent reside in the villages and form the backbone of India's many homes. Those who live in our towns have opportunities of contact which help them to develop and to keep pace with modern ideas.

While the towns women also need your assistance, I wish to dwell to-day more particularly on the problems of our village women in their mud huts and behind their mud walls. It is these women and their men-folk on whose lives so much of the future of this country depends.

Politicians and economists often tell us that it is not of much use trying to improve the homes of our villagers until we have added substantially to their incomes. Higher incomes they say are necessary if they are to clothe and feed themselves properly, keep themselves clean and live in healthy if not attractive surroundings. While there is much force in this argument, I do not see how you are going to provide an incentive to these men and women to increase their incomes, if you do not show them some of the excellent ways in which they can spend additional income, for example by building and maintaining decent homes You will of course be up against all sorts of difficulties in the village There is the accumulated tradition of centuries, custom, superstition, religious practices and the characteristic factor of prejudice against change. Some women in the villages may tell you, for instance, that they know more about the care of children under village conditions than you do. This reminds me of the story of the British Sailor who at a Hollywood Canteen complained of a sore throat. Some kind lady asked him if he had tried gargling with salt water. "You 're asking *me*" said he "who has been torpedoed three times ?"

Although you will find the average village woman somewhat difficult to interest in things which cost money she may be greatly interested in things which cost next to nothing and yet make the mud hut more habitable and the home more attractive.

You might, for instance, persuade the house owner to give a slope to the ground round the outer wall and on the veranda, if there is one. This with a drain to take off surplus water should be easy and inexpensive. Then, ventilation and an improved fire place, simple home-made articles of furniture such as those I saw to day in a model house which Mrs. Higginbottom has built in a village 4 miles from here, a roof that does not leak : all these would be beginnings in the right direction. You will also come across village women who want to look well dressed. At a wayside station recently I saw more than

one typical village woman wearing high heeled shoes I daresay if you looked closely into the belongings of these women, you would discover powder, a mirror and possibly trinkets. This only confirms my belief that our village women are not entirely blind to visible signs of change in the outer world and the imitative faculty is well developed in every human being. This is all to the good and a close study of our poverty ridden village homes would, I am sure, reveal much that should encourage the enthusiastic reformer. Empty stomachs and empty pockets are of course a great hindrance to progress; but this war is like an ill-wind that I think has blown some good to India. The cultivator along with many others has paid off much of his debts and has in many cases put by some cash If therefore you still find empty stomachs in famine stricken areas, there are also plenty of places where the villager is better off than he has been for a long time.

Recently, we read in the papers about a plan of Post War Reconstruction wherein no less than 10 thousand crores of rupees were to be spent to solve most of the country's economic problems. One of the items in this plan concerns the the use of cement, bricks and iron in our villages. Prof. Rudra and I were discussing this plan a few days ago and we tried to picture in our minds a large building in every village made of bricks, cement and iron. Here are some of the sections which I visualise such a building would contain :—

A large open shed where the harvested crops should be saved during bad weather;

Underground grain-stores;

A bureau of information with a library;

A school room for adults and another for children;

A hall for meetings;

A small dispensary;

A recreation room and, last but not least,

A small model home.

The whole village would run as one co-operative society, would own the new building as soon as the cost had been paid up and would benefit by all that co-operative effort implies. Taking a single advantage of such a scheme, the cement concrete storage for the growers' produce would save the villager some of the enormous yearly loss which he suffers through his being at the mercy of the middleman who is generally also the money-lender. The additional income from this item alone would help to build new and better homes and to provide such amenities of life as had never been known in the village before. With the elders of the village meeting frequently in such a central building symbolising as it would unity and strength, it would be reasonable to expect that

in time such essential changes as the consolidation of holdings, the prevention of soil erosion, co-operative marketing and other co-operative effort all of which would add to the villagers' income, would follow as a natural result of such a beginning. The State may or may not raise a large sum of money to put such a plan into action; but India has never been lacking in philanthropic men and women; neither is our country poor in educated young men and women who are fired with patriotic enthusiasm for social service among our needy millions. What the State may not or cannot achieve can certainly be achieved by organised effort on the part of individuals or groups who are determined by practical demonstration and persuasion to improve our village homes. Our big men of industry, our contractors and middlemen, our landlords and bankers—all except Government servants and missionaries—are making plenty of money. What could be a better investment than advancing 20 or 30 or 40 thousand rupees to a village co-operative society in the shape of a central village building of the kind I have just described? In years to come when these rich people see the progress and development they have helped to achieve, it will do their hearts good, and a prosperous village will pay back the capital in due course and possibly some nominal interest as well. I was discussing the construction of reinforced brick wells with an engineer the other day and he assured me that with a lining of single bricks in cement with iron reinforcement, it should be possible to make a well at about a quarter of the present cost of a brick well of the usual kind. To a cultivator of 5 acres, this would mean these days an additional net income of about 1,000 rupees per annum. With a plantation of papayas such as you have here it might well mean 3 or 4 times that income.

So much for the possibility of providing the wealth that will help us to achieve our object quickly.

The problem for those who are trained in Home Making is to rouse the interest of the womenfolk of our villagers in the improvement of their homes to make them more attractive and comfortable, by teaching them better ways of utilising their existing resources creating more hygienic and attractive living conditions. A small vegetable patch, a few flowers, cleaner houses, cleaner streets and lanes, better drainage, all these are achieved at little or no cash cost.

I have said that unless you have a model home in the village you cannot provide an incentive to the villager to improve his standard of living along the lines indicated by your model home. In any Post-War Reconstruction plan, it would be of the greatest importance for Government or some patriotic people of wealth to take up the building of at least one model house in each village. One of the more prosperous tenants should be induced to live in such a house and to benefit by all the various improvements suggested by the homes in the rural areas of other countries.

In order to make such an experiment a success, it will be necessary for voluntary workers who have received training in Home Making to live in the villages. It might be desirable for two model houses to be built in each village, one to be occupied by the Home Making expert and the other by one of the villagers with his family. By day to day contact with the life of that family, the expert would be in a position to suggest improvements and get them carried out on the spot I was struck by an example of such improvement having been brought about in a small village in the Punjab which I visited recently where the owner of some land, an Indian Christian lady, built a house for herself and her husband. She remodelled all the houses of the tenants who are now living under conditions so far advanced that they would never consent to go back to the old unhealthy mud huts. The new houses are built of sun-dried bricks and of clay and cow-dung plaster. Wood rafters, ventilators, decent windows and doors, verandahs, housing for cattle, bathing places and well regulated manure pits, have all contributed to the well-being of this small colony who are far happier than the people who have not been able to do like wise. This village got the prize for the best houses in the entire district under the Punjab Government's Rural Development Scheme The only flaw in this instance was that the lady in question and her husband lived in a small bungalow in the village rather than in mud houses like the others. My suggestion would be that our Home Making experts should settle in the villages for a sufficient length of time to bring about the necessary improvement and they should live in houses such as those which it is intended that the villagers should make. The village home must be such as to keep the people in good health and to create a feeling of well-being. It was a pleasure to see in the houses of the village I have mentioned, a clean row of cooking utensils neatly arranged on brackets. Spotlessly clean glasses, *katoris* and *thalis* were also in evidence. The clothing was in boxes raised from the ground on brick supports and foodstuffs were kept free from rats and dampness The entire family sleep on beds. The cooking is done in the verandah in such a place that the smoke does not worry the family. I observed an absence of flies and mosquitoes. The place was clean. The clothing of the people was also clean. Although they have not learnt the use of soap, yet they use *besan* and similar simple substitutes for soap. Their children looked healthy and clean. The cattle manure, an important factor in the economy of the village, was kept in covered pits some distance from the houses. Open troughs were provided in the court-yard where the cattle were stalled in clear weather. Water was at hand from more than one hand plunger pump. The women wash their hands before milking their cattle. The villagers each possessed a lantern and there was no evidence of smoke blackened walls. They had plenty of butter milk to drink and wheat

and maize, flour and *ghee* to eat. This is surely an achievement worth emulating elsewhere.

That the problem is a tough one we must all admit, but surely it is time that we had a large band of voluntary women workers trained in Home Making and prepared to rough it in the villages in order to raise the standard of life of our less fortunate sisters. Literacy, schools for needle work, basket making, fan making, rope making and the like are all things which can be organised only if there is someone on the spot to be a guide, philosopher and friend to the village peoples. Preaching from the platform, distributing leaflets, an occasional visit by an official, cinema or magic lantern shows, all have their uses; but nothing of that kind can be really effective in bringing about a real change. This will depend on the missionary zeal of our own women who have had the benefit of a good education and special training in Home Making. I have been reading a book entitled "Prophets of the New India" and in describing an incident in the life of Swami Vivekananda the author tells of one of the disciples of the Swami who objected to the difficulty of establishing unity and harmony in India. Vivekananda replied with irritation :—

" Don't come here any more if you think any task too difficult. Through the Grace of the Lord, everything becomes easy of achievement. Your duty is to serve the poor and distressed without distinction of caste or creed. What business have you to consider the fruits of your action? Your duty is to go on working and everything will set itself right in time . . . You are all intelligent boys and profess to be my disciples—tell me what you have done. Couldn't you give away one life for the sake of others? Let the reading of the Vedanta and the practicing of meditation and the like be left to be done in the next life. Let this body go in the service of others and then I shall know you have not come to me in vain."

Some 1900 years before Swami Vivekananda, there lived one greater than him who one day addressed his beloved disciple three times with the words "Simon Peter, lovest thou me" and when exasperated by the thrice repeated question his disciple said " Yea, Lord ; thou knowest that I love thee." The Master's command was " Feed my sheep." This was not only in reference to just ordinary food. It had a higher significance which included work among mankind, raising their mental and spiritual outlook and making them long for things which are conducive to happier and cleaner living. No time could be better than the present to commence work in our villages to make the village home a better place to live in. As I have said before, the high prices of agricultural produce have brought some prosperity to our villagers. Many of them don't know how to spend the money which they have made. Surely this is an opportunity worth grasping by the forelock. Some will hesitate to join this band of voluntary workers which the country needs so badly and should

you be one of those who join it you will find innumerable difficulties facing you. There will be disease. unhealthy conditions, exhaustion, disappointment and even rebuff to face. While I congratulate you on the diplomas which you will receive to day, I can only hope that you will take courage in both hands and start such a movement. It will be a glorious day for this Institute when the handful of women who are turned out as Home Making experts, form the nucleus of such a band of voluntary workers as I have referred to. I do not expect each one of you to be a Mrs. Higginbottom or a Mrs. Wiser or a Gertrude Emerson, but I do expect our women to have the courage of leadership and to make the most of their education and training. The example of those I have just mentioned and of others who are giving their lives to the services of our ill-fed, ill-clad, uneducated millions should inspire you and encourage you to take up this great task. But we must bear one thing in mind. The villager or any one else whose way of life you wish to reform might be put off or frightened, if you cram a lot of new ideas into his or her mind all at once. This is a real danger and you must guard against it. Be content with small beginnings. Take up a few items of improvement and when yon have proved these to be really good and desirable you will have gained the confidence of the village. The rest of your task will then be less difficult.

Finally, when you go to the villages and find many difficulties, disappointments and rebuffs, here are some lines from Browning which may cheer you :

"Then welcome each rebuff that turns live's smoothness rough,
Each sting that bids nor sit nor stand but go ;
Be our joys three parts—pain, strive and hold cheap the strain
Learn nor account the pang ; dare, never grudge the throe."

FARM POWER FOR INDIA

By

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The power available for performing agricultural operations has been an important limiting factor in agricultural production since the beginning of farming. Probably originally all operations in producing crops were done by human labor, the power produced by human muscular effort. Human muscular power is still used to a very large extent in Indian agriculture and to varying degrees in other countries Long ago, man domesticated various animals and has since used the power of their muscles to supplement, or as a substitute for, his own efforts. Practically throughout the world the

bovine species have been so used. In many countries the horse and the mule have been widely used and in western countries they have largely supplanted the bullock as a source of farm power. Quite recently in comparison, mechanical power produced first by the steam engine and later by the internal combustion engine and the electric motor has come into use and in some countries has largely supplanted all animal power. In no country has animal power been completely supplanted. The process has gone farthest in the Americas, particularly in the U. S. A. and in Canada, and in Australia and New Zealand The use of mechanical power has increased tremendously in Russia in recent years and particularly during the war, in Britian. This tendency to substitute mechanical power for human and animal effort has been least in Asia, and Indian agriculture has, on the whole, been very little effected by it as yet.

War conditions have increased the already growing belief that there is urgent need to improve Indian agriculture, particularly with regard to the implements and machines used and the power used to operate them. Where formerly it was thought by many that there were inexhaustible reserves of labor needing employment in India and capable of supplying all needs, the war has accentuated and brought sharply to attention a shortage of labor, which has been developing for some years, at certain seasons and particularly in certain areas. It has been commonly recognised that the ordinary Indian bullock was not an entirely satisfactory animal and there has been a good deal of attention to the introduction of improved bullocks both by breeding and by importation from areas where superior animals are available. These efforts have been hampered perhaps by the continuing, and at times acrimonious, controversy as to whether it was possible to produce a dual purpose breed of animals in which the males would be efficient workers and the females efficient milk producers.

Until recently very little attention has been given to the possibility of the use of mechanical power in farm work. It was generally accepted by agricultural workers that so far as the ordinary cultivators were concerned, there was no place for mechanical power in India. In comparison with the power developed by bullocks, the use of mechanical power has been insignificant and the little use there has been has been almost entirely confined to sugar factory estates, Government farms and a very few large cultivators. Lately, under the influence of the publicity given to developments in Russia and to a less extent in other countries, a considerable amount of interest has been aroused in the possibility of the use of mechanical power and opinion has tended to swing from indifference or active opposition to the other extreme of advocating the rapid introduction of large scale use of mechanically operated farm machinery, with the easy assumption that the whole social and economic system should be compulsorily upset if necessary to bring this about.

It has seemed to the author that both these points of view have been uninformed and based on incomplete understanding of the situation and of the problems involved. It is the purpose of this paper to examine the possibilities of the introduction of mechanical power in Indian agricultural practice, the difficulties involved and advantages to be gained. It is hoped that such an examination will provide a basis for reasonable planning and propaganda both in the near and in the more distant future. The thesis to be developed is that there is a definite place for mechanical power in the development of Indian agriculture but that that place is sharply limited and that on the basis of present knowledge we should not expect mechanical power to replace animal power. Its function according to the author's thesis, is to supplement animal power in sharply limited fields, at least in so far as the immediate future is concerned. A part of the thesis which is considered very important is that the application of animal power should also be improved and the efficiency of its utilisation should be increased as much as possible. The reader is asked to go through the following discussion carefully before taking sides on the proposition or attempting to reach a conclusion.

For the purpose of the discussion, let us consider the application of mechanical power to agriculture under three hands as follows: (*a*) the reclamation and development of previously uncultivated land, (*b*) stationary power used at the farm-stead for feed grinding, fodder chaffing, pumping of irrigation water and crushing of sugar cane, and (*c*) field operations involved in the growing of crops. It will be convenient to divide the subject because the type of work to be done and the type of power unit suitable for doing it is quite different in each case. Any one of the three applications can be done separately without involving necessarily the introduction of either of the others. In general, the apparatus used for one is not adaptable for use in either of the other applications, except that tractors can be used for stationary work.

Application (*a*) has an important if somewhat temporary place particularly in the early post-war period. Conditions will then be particularly favourable for this use of mechanical power. Presumably there will be large numbers of army machines which will be more or less adaptable to such work. Some of them such as the large tractors fitted with road making machinery or those used to pull big guns about will need little or no adaptation. Others such as the "jeeps," which have captured the popular imagination for certain things they can do, will need extensive adaptation and even then will likely be less suitable than machines made for the purpose While powerful in their way, they are not in the class of equipment particularly suited to agriculture or reclamation work. A drawback to most of the army power units is that they are built to burn petrol and cannot be satisfactorily converted to other fuels. While undoubtedly there will be petrol avail-

able, unless government revises its present tax policy to make available petrol free of the present tax charged on petrol used for transport vehicles, the operation of power units on petrol costing around Rs. 2 per gallon is likely to be uneconomical. It may be cheaper to scrap the army units and buy new units operating on cheaper fuels not subject to the tax burden.

Whatever the source of the power unit, there is a definite need for the reclamation of potentially fertile land at present lying uncultivated. According to the census figure, the culturable waste is approximately equal to the cultivated area. Most of the culturable waste is uncultivated because men cannot clear and cultivate it and make a living doing so under existing conditions and with existing commonly used equipment. The large tractor and its associated implements is very well suited to clearing jungle, to levelling and to certain types of drainage and erosion control construction. Certain types of drainage and irrigation construction can be very economically carried out by mechanically powered equipment specially constructed for such work but ordinary types suited for cultivation or army salvage equipment will not be suitable for all kinds of such work. With such equipment operated by capable mechanics and under plans drawn up by qualified men, it is possible to bring large areas, at present uncultivated, under profitable cultivation. Most if not all of the units required for such work must be mobile and in most cases will need to be tractors As strictly reclamation procedure, this use of mechanical power will presumably be strictly temporary. Eventually, the cultivable waste would all be brought under cultivation and there would be a limit to the expansion It may take a long time but the period is limited and would be determined by the rate at which the work is carried out.

The fact that the use of stationary power units are more easily introduced into present Indian agriculture is demonstrated by the extent to which they have come into use. Particularly on Government farms but to a considerable extent on privately owned farms, power units have been installed in large numbers for pumping, in considerable numbers for crushing sugarcane and to a very limited extent for other purposes. A related semi-industrial use of power has been the widespread use of the oil engine driven flour mills in rural areas as a substitute for doing the work formerly done by human muscles. Not only has this type of use been most widely adopted, but it offers most scope for further immediate introduction. There are many reasons why this type of power driven equipment is more readily adopted. Quite small units can be secured and usefully used. Because they are installed in one place and not required to be moved around, the construction is simpler than that required for mobile units and the cost per unit of power is less. The greater simplicity makes for easier operation and requires less skill on the part of the operator. The pre-war cost, ranging from around Rs. 50

to 150 per horsepower of capacity, compared favourably with the cost of bullocks to do the same amount of work. The overhead cost when not in use is low as little or no maintenance is required when idle The mechanical power unit can be operated long hours daily when necessary, even right round the clock. Most of the small units work on either kerosene or diesel oil or more recently in the grid areas on electricity. Electric motors are the ideal form of small power unit for stationary operation in agriculture and as the hydro-electric and steam generated electric grids are extended there will be a large extension of the use of these units. In addition to individually owned and operated units, these stationary units lend themselves to state or community ownership and operation. Water can be pumped from a central well and supplied to individuals over a wide area. Grain to be ground can be brought easily to a central place whether for human food or cattle feed. At least in some cases, it will be comparatively easy to locate silos for a number of people in a village at one place, making possible the use of stationary or semi-portable units for silo filling. The use of such small stationary or semi-portable power for the kind of work which is done in one place is most readily introduced into the present situation as it requires the minimum adjustment of present practices and of village social organisation. It seems certain that such stationary uses will very rapidly increase and that in the operation of them many of the men trained in the army will find suitable employment for their newly acquired skills.

Our third application of power, that of the use of mechanically powered units—tractors—in routine field operations such as seed bed preparation, the seeding, cultivation and harvesting of crops, presents far more difficulties. At present, I see very little scope or need for this kind of power in Indian agriculture nor do I see much reason to expect its use to become general. There is certainly great need for improving these operations. Under present conditions, the power available is at times a limiting factor. Mechanical power in the form of the tractor has many attractive features. Under certain conditions, tractors are useful and economical. These necessary conditions do not exist at present in ordinary village agriculture, nor do I consider it practicable to provide them.

The conditions necessary for the successful use of tractors are skilled personnel, suitable total areas available for use during the year, suitable distribution of work through the year and suitable size of fields. Much has been said recently about the thousands of men trained in the operation of motor vehicle by the army in the last few years. While it is true that thousands of men have been trained as drivers, it should be kept in mind that *driving* of agricultural tractors is a simple operation easily learned. The skill that is needed much more than driving is that necessary to proper maintenance. Knowledge of the implements, their care and proper operation is as important as

knowledge of the power unit and this training is entirely lacking in the army training programme. While it is easier to add it to men already knowing the maintenance of the vehicles than to train completely new men, failure to recognise the necessity of the additional training in the use of the implements is to invite failure of the whole programme.

Granted that the war has made a great change in the enlarged supply of partially trained personnel, what of the other requirements? The total cultivated area in a village is enough at least in most cases if the village organisation is suitable to make possible the use of a tractor. The distribution of rainfall and other seasonal changes makes somewhat difficult the best distribution of work, but that also is possible of adjustment if suitable planning is carried out. No one cultivator in most villages has enough land, even if it were consolidated into one block to economically utilize even a small tractor. Even with consolidation of holdings and even with consolidation of cultivation into blocks where only one crop is grown, the areas available in the village for the use of a tractor would be limited. With such consolidation, any one cultivator would still have a small plot only for any one crop season. How far cultivators will be willing to have all field boundaries ploughed up and re-established annually seems to me problematical. While the consolidation of cultivation by which all the area under one crop in a particular village, in a particular season is in one block, undoubtedly has certain advantages, it appears to me to have grave disadvantages also. It was something similar to this which held up progress in the use of better implements in England. The change from this system or an approximation of it, the giving of each farmer his own farm on which he could plant what he pleased and on which he could reap the benefits of increased skill and industry, led to the tremendous development of agriculture which occurred in the last two centuries in the West. While such consolidation may simplify irrigation, it seems likely to intensify other problems particularly of disease and insect control and to involve a degree of regimentation which will neither be welcomed generally by the cultivator or be in the best interests of the country. It may work better in areas where one or two commercial crops like sugarcane or cotton are most widely grown than it would in areas of diversified cropping.

Even if we accept for the moment that the consolidation of holdings and of cropping is both desirable and feasible, does that still make any place for a tractor in a village even if we assume the availability of the necessary trained men? There are two ways of utilising a tractor (1) the complete conversion of the whole process of cultivation to tractor power with the resulting elimination of animal power and a reduction in the number of men required for field work, and (2) the use of the tractor for certain types of work, leaving the remaining work to be done by animal power or hand labour. While the latter method was tried in the early stages of the introduction of the tractor

in America and elsewhere, the successful use of the tractor has always been where the conversion has been complete. The tractor did not come into wide use or popularity until the International Harvester Company with the "Farmall" introduced the cultivating type of tractor with which all the operations formerly done by animal power could be done with the tractor and its associated implements.

The most widely advocated use of the tractor in India for general cultivation has been that it be used to do the heavy ploughing for the whole village, leaving the rest of the work to be done by the cultivator with his oxen. This seems to me to ignore the accepted and proven teaching of both economics generally and good farm management in particular. Under such a system, the tractor could be used for only a limited season, being idle the rest of the year. It is no good airily suggesting that it be used for breaking up new land or for other work unless it can be demonstrated that such alternative work is available within the season when the tractor is otherwise idle. Similarly, under this system, the oxen would be idle during the time that the tractor is being used. This involves double investment in both oxen and tractors. The income from the cultivation must carry the cost of the capital involved in this double investment. Repeated farm management studies in America, where the tractor has been most widely used and where there is the greatest experience available with it, have consistently shown that the best profit results from the use of either tractor or animal power for field work, not from the use of a combination. I have studied the theoretical application of the figures obtained from American conditions and have found no reason to believe that there is anything to lead to a different result in India. The only exception I have found to the above has been the case of the large sugarcane plantations which have used both tractors and animals during a period of development of new land when the tractor could be used, when it was not required for the heavy ploughing, to break up new areas which were turned over to animal power for later operations.

Many of the most enthusiastic advocates of the tractor recently have based their advocacy not on economics of the use of the tractor but on the premises that improvement was necessary and that it could only come through the use of the tractor.

Accepting that improvement in our cultivation is necessary, it does not necessarily follow that such improvement is entirely dependent on the introduction of the tractor. Practically any necessary, annually done, field operation which can be done with a tractor can also be done with animal power, provided suitable implements are selected Very little of the advantage of the tractor is in *what* it can do. The advantage is almost wholly in *how much* it enables one man to do in a given time. This being true, improvement in the technique of agriculture is not dependent on the tractor; a *particular system* of farm management may be possible only when a tractor

is available, whether the system involves the use of a tractor only or of mixed power.

If we accept the above, what is the position ? I see it as follows : There are a limited number of estates in India now which are large enough and suitably located for conversion into fully tractor operated farms. There is land available in certain areas from which tractor operated farms can be developed. Though such a development is possible, I doubt whether the development of large scale tractor operated farms from this area is socially the most desirable development from the view point of the state where there is as dense a population as in India. It may be much wiser as a matter of economic policy to develop the available land into family size smaller farms, so providing for a larger number of families to be accomodated on the land.

Perhaps this statement needs a bit of further elaboration. I am quite familiar with and accept the view that improvements in productive methods and equipment do not in the end necessarily lead to unemployment. I fully believe that it will be possible to develop industries only as labour is released from agriculture and made available for industrial employment. I fully believe that India should develop her industries to the fullest possible extent which may be economically feasible. However, it is also true that even if half of the total present population is transferred or transfers itself from agricultural to industrial occupations and if all the waste land is brought under cultivation, the average area available for each farmer will be roughly four times that now cultivated. In most parts of India the ultimate area would be somewhere around 30 acres. This takes no account of the large increase in population which is still going on and part of which must be accomodated on the land. So far as I can see, unless there is a drastic reduction in the population or unless there is the possibility of accommodating a far larger part of the population in industry than now seems likely, for more than the 75 per cent. so employed in the West, India must continue to be a land of comparatively small cultivators. Therefore, while we should believe in and try for technological progress, we will get results faster and with less suffering if our technological progress is such as can be applied in the fist instance to existing conditions. If that progress can be part of a continuing programme or in preparation for it, so much the better.

While it is true that the release of a large part of the population from agricultural work and the re-employment of it in industry is the only way in which we can hope to raise the standard of living, too rapid change can result in intense suffering, because too rapid change is likely to be unbalanced change. I am anxious to have the change take place as fast as may be possible but it should be recognised that there is no gain to the individual concerned in exchanging a pittance

for complete unemployment even though the exchange may resuly in gaining affluence for his son. Too rapid absorption in industry mat result in acute difficulties on the farms as has happened in many countries as a result of the present war. The absorption in India of a few million people into war industries and the army, possibly 2 per cent. of the population, has caused acute difficulties in many areas. What would be the result of releasing 50 per cent. from agriculture without a corresponding rate of absorption into industry ? While it is true that "gradualness" can be overdone and often is, it is equally true, that excessively rapid social and economic changes can be much overdone also. Social and economic changes take time. It is largely the younger generation which can adapt itself to new occupations and to new techniques. There is ample scope for rapid and effective advance which will result in great improvement without the complete and sudden overthrow of the whole social and economic system. The old admonition against "biting of moret han one can chew" is applicable to economic and industrial—and agricultural—progress and improvement as well as to eating.

If this contention is accepted, we can sum up by saying that there is great scope for the use of large scale power units and their associated implements in reclamation of uncultivated land ; there is large scope for the application of mechanical power to stationary uses in connection with agriculture; there is at present little scope for the application of tractor power to field cultivation in the village. The power units available at present are not suited to individual use because they require, to be economical, more area than is available to the individual ; and community use involves combined use of tractor and animal power which has not proven economical. This is an assessment of the present situation which may be changed by future developments, of course, particularly developments which might make a small tractor available at costs comparable to cost of bullocks.

It appears therefore to the author that the immediate future requires the fullest possible development of the use of animal power and the implements to make it effective. Experience shows that it is possible at relatively small capital expenditure to make very great improvements in the implements now in use which will in turn result in much more economical utilisation of animal power. There are also great possibilities of improving the animal power both in quality and in quantity. The animal power at present maintained on the farms is very poorly utilised and is poor in quality.

This aspect of the subject must wait for a later paper. Briefly, there are two phases of it, (1) the better utilisation of the animals now in use and (2) the utilisation of animals not now used for draft but capable of being so used, particularly the large number of females now maintained which give little or no milk. It is proposed to deal with this in a paper to follow this.

A SURVEY OF THE COTTON WILT DISEASE IN INDIA

BY

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INTRODUCTION

Wilt disease of cotton causes a considerable loss to the crop in India. It occurs in almost all the cotton tracts in India excepting the Punjab, North Gujrat and Sind. Bombay Presidency, Berar, the western parts of the Central Provinces, the northern parts of Mysore and the Malwa plateau are amongst the greatest sufferers. It is also found, to some extent, in the western parts of the United Provinces. The portions of the Nizam's dominions adjoining the wilt areas of Berar, East Khandesh and Dharwar also suffer from wilt; and, according to Sawhney (1938), the disease may become one of the major problems in the State.

No attempt has been made yet to estimate the quantitative damage caused by the disease in India, but some idea can be formulated by the fact that for the Bombay Presidency alone the loss, as reckoned by Kulkarni (1934), comes to about 4 million rupees annually.

THE CAUSATIVE ORGANISM AND THE SYMPTOMS OF THE DISEASE

Evans (1908), Butler (1910 and 1926), Ajrekar and Bal (1921), attributed the disease to the fungus identified by Atkinson (1892) as *Fusarium vasinfectum.* Dastur (1924) considered wilt to be due to toxity caused by the absorption of aluminium compounds by the roots. Uppal has not only established the pathogenicity of the fungus *Fusarium vasinfectum* but has also shown that the fungus is very virulent under suitable environmental conditions.

The symptoms of the disease are so marked that it can be identified easily in the field. The fungus as it develops within the tissues of the roots clogs the xylem vessels and thus obstructs the passage of water and food material to the upper portions. The wilting usually starts in the leaves from the base upwards causing them to turn yellow and then brown. The shoot hangs down limply and the plant ultimately withers and dies. Sometimes when the attack is severe the plants die suddenly. The disease may appear as early as a week after germination of the crop and plants may succumb at any stage of their growth. Even tall vigorous plants have been seen to die as late as at the stage of maturity, The plants with partial attack

are quite common. Completely attacked plants without any leaf or even shoot often revive giving out new shoots. The affected plants do not show any discolouration externally either on the stem or root. In the early stages of the attack if the root is split open, yellowing of the vessels and the surrounding tissue will be noticed which at a later stage look like black streaks along the vascular strands.

Wilt Resistant Strains

At Poona, Uppal has produced two strains, Chinese Million Dollar Spotless R. 51 and New Million Dollar, which are 100 per cent. wilt resistant under optimum conditions of wilt infection. Some of the other notable wilt resistant strains are the *Verums*, covering an area of about 109,233 acres in the C. P. and Berar, Jaywant with an area over 500,000 acres in Dharwar, Belgaum and Bijapur, and B. D. 8 and Jarilla extending to about 30,000 acres in Baroda district and Khandesh respectively. Dharwar 2, wilt resistant Kumpta, Wagale (a Burmese cotton), Comilla 4-2, a selection from Assam cottons, are another set of wilt resistant varieties. A sub-strain of Malvi 9, and C. 520/9 a sub-strain of C. 520, are the promising wilt resistant strains for Malwa and western U. P. respectively. This, however, exhausts the list of the wilt resistant strains in India. Looking at the country wide damage, caused by the disease, the work accomplished is extremely meagre particularly when we find that most of the strains are in the initial stages of distribution. Much, therefore, is to be done towards breeding and extension of promising strains, till every cotton growing tract can have its resistant strains.

Correlation of wilt Disease to other plant Characters

Weaver (1926), in his classical study of roots of field crops, suggested selecting plants whose roots are resistant to fungus attack as a primary procedure. Kulkarni (1934) studied root systems of certain varieties of cotton with regard to wilt but did not come to any conclusion. The plants studied by him were very few in number. Ramiah and Ansari (1940) carried out investigation on this problem with Malvi cottons and found resistance to be associated with greater number of lateral roots not only between different strains of Malvi cottons but also within the strains. As such differences within a strain can only be attributed to linkage or physiological association, advantage can be taken of their existence for single plant selection based on desirable root characters. In cases like these it would be interesting to know whether a thick root is endowed with thick epidermis also and consequently is able to resist the attack of the fungus, or that its large diameter along with other characters is sufficient to confer resistance to it.

Another kind of correlation is that recorded by Ware (1932) who found susceptibility to be associated with earliness. The fact that a study of correlation of the disease with plant characters would be of immense value to plant breeders needs no emphasis.

CONTROL OF WILT

Kulkarni (1934) found that soil temperature plays a dominant part in the development of the disease. He has shown that under Dharwar conditions by sowing the crop early *i. e.*, in June and July the period of optimum activity of the causal organism was skipped over, and therefore, the yield obtained was greater than that of the normal sowings in August. The experience of Patel and Kulkarni (1940) is that at Broach the expression of wilt takes place when rainfall and temperature are favourable Studies on wilt at Raya farm, district Muttra, have yielded very interesting results. It has been found that there is a strong correlation between the incidence of the disease and rainfall and humidity, the attack being particularly severe during the months of July and August and sometimes in September also when the rainfall is high and the humidity ranges from 80 to 90 per cent.

The application of organic manure to control wilt has given different results with different workers. Low (1938) records for Malwa that good soil and manuring favour the incidence of disease in *arboreum* cottons. Dastur (1929) also found organic manure to increase the incidence of the disease. Kulkarni (1934) however found that farmyard manure in heavy doses of 40 tons per acre controls the disease in the later stages of the crop.

Data on the relationship of inorganic manure and the control of wilt is extremely meagre. While Kulkarni (1934) records that the cultural and nutritional study of the fungus does not indicate any marked decrease of the disease with the various manurial treatments, Young (1938) found that application of potash alone as kainit often gave better control of wilt on both the susceptible and the resistant varieties of cotton.

Some interesting observations are also available on the effect of intercropping and incidence of the disease. Reports from Uganda (E. C. G. R. 1939-40) show that wilt was less prevalent in closer spacings and also in the interplanted plots, indicating that the incidence of wilt may be reduced by shading.

In Malwa, desi cottons when grown alone suffer greater mortality from wilt than when grown as a mixture with American cottons. Experiments carried out at Indore, have given similar indication (I. C. C. C. Report 1939). Probably the American cottons on account of their large leaves and spreading habit serve to reduce the air temperature by shading. This, in addition to their immunity to wilt, may

further be retarding the growth of fungus at the spots covered by them. It would, however, be interesting to find out in what way American cottons tend to protect the *desi* cottons from the attack of wilt. A knowledge of the effect of intercropping of cotton with other crops on the incidence of the disease would also be very useful.

It has been found by Elliot (1923), Crawford (1923), Taubenhaus and Ezekiel (1932), and Kulkarni (1934), that the seeds obtained from wilted plants serve as carriers of the fungus. The results obtained by these workers show that it is unwise to distribute a susceptible strain and the seeds obtained from wilted plants, for they serve as the starter of the disease. In fact, this has been regarded as the chief reason for the occurrence of the disease in new areas. Seeds from wilted plants can be eliminated by roguing out diseased plants. Roguing of diseased plants, if done in earlier stages, would also be a good sanitary measure as it would serve to eliminate one of the sources of the survival and distribution of the fungus. Where large plots are concerned and roguing has not been possible till the picking time the best way would be to condemn the produce of the diseased patches rather than allow it to mix with healthy seeds and run the risk of spreading the disease.

While the treatment of seed with chemical reagents such as sulphuric acid, formalin, copper sulphate, etc., has proved useful in the case of external infections as cereal rusts and mildews (Koeholer B), and also in the case of Angular leaf spot disease (E. G. G. C. 1939-40), the results obtained by Kulkarni with regard to wilt are inconclusive.

Since the fungus is a saprophyte and can survive in the soil indefinitely, it is doubtful if any method of crop rotation would be very efficacious.

Lastly, it may be emphasized that the measures of control would not be very successful if the strain of cotton grown happens to be highly susceptible. Other factors being equal, the greater the resistance of the variety the more satisfactory will be the control of wilt.

Tackling the problem.

It would appear from what has been said above that the production of wilt resistant strains remains the only satisfactory method of combating the disease. The Indian Central Cotton Committee, in March, 1937, passed a resolution that although breeding of immune strains was the ideal to aim at, 95 per cent. resistance in a strain for agricultural distribution should be enough, if the strain is true for that degree of resistance. The justification of breeding upto 95 per cent. resistance, would be obivious from the experience of the Egyptian workers, where it is stated (Brown 1939) that "Selection in strains for immunity have in all cases been associated with slight but signi-

ficant differences from the original strain in one or more characters". Further it is extremely difficult to get an immune strain possessing other economical characters also. To quote Mr. J B. Hutchinson (1938) "Supposing there were ten factors for wilt resistance and ten factors for staple length, only one in a million could combine all these factors". The resolution passed by the Indian Central Cotton Committee, therefore, clears up a long misunderstanding of the problem and serves to save a good deal of the valuabletim e of the breeder.

The cotton committee reports show that wherever schemes for evolving wilt resistant strains are in progress, both progeny row selection and hybridization followed by selection are being tried. If the local material shows enough of variability in resistance to wilt, straight selection should be given preference over hybridization. Unfortunately, the breeder often finds to his dismay that his commercial strains are lacking in resistance to disease. Dharwar 1, Banilla, Goghari A 26 of Gujerat, Malvi 9, Gorani 6, K1 and C. 520 are some of the instances. The reason is that during the process of selection all efforts were directed towards improving the commercial characters thus eliminating unconsciously the genes carrying wilt resistance. It should, therefore, be the rule with every plant breeder that selection for disease resistance should proceed simultaneously with that for economical characters. The best way would be to test a part of the material on wilt infected land also. Another method would be to breed *resistant bulks.* It would be useful particularly for places where there is a wide range in fluctuation in soil and climate to take one or more commercial strains of the locality and grow their survivors year after year separately in a wilt affected land till a bulk with suitable resistance has been evolved. Some of the single plant progenies of suitable crosses, if found promising, even at earlier stages of selection, can be bulked up and similarly tried. Such a mixture would provide a highly variable material for single plant selection.

Besides the one sided selection ignoring the characters for wilt resistance, there may be yet another cause of their susceptibility to wilt. This is when the disease is of recent origin in a particular tract and consequently the improved strains of the tract could not be tested for wilt resistance in earlier stages of selection. In cases like these, hybridization with a highly wilt resistant strain can be resorted to with advantage. Uppal's work shows that crosses with B. D. 8, New Million Dollar and Chinese Spotless R. 51, hold promise for Surat, Jalgaon and Broach tracts. In such cases backcrossing the hybrid with the resistant parent yields more resistant material than the straight cross.

It is interesting to note that exotic cottons, such as Cambodia, various American and Egyptian cottons are not known to suffer fro m wilt in India. Recent work on interspecific crosses (Amin 1940) open s up a possibility of transferring immunity genes from American t o

Asiatic cottons Knight and Clousten (1939) have already achieved success in transferring blackarm resistance of a strain of American cotton to an Egyptian type.

The experimental design that can be recommended for testing varieties for wilt resistance, under conditions of field infection, is Replicated Randomised Progeny Row technique. The wilt studies at Raya farm, Muttra district, (Sethi and Ansari, data unpublished), show that the technique has proved to be very efficient in selecting for wilt resistance, yield, and quality, in C. 520 strain which was under distribution for the last 17 years and was assumed to be breeding true. Nine sub-strains of C. 520 *i.e.*, C. 520/1 to C. 520/9 were tried for disease resistance and other economical characters and it was found that within a short period of two years the range of mortality for these sub-strains narrowed down from 10 to 89 per cent. with a mean of 72.8 per cent. to a range of 0.5 to 42.8 per cent. with a mean of 32.5 per cent. The sub-strain C. 520/9 was found to be resistant from 96 to 99 per cent. under conditions of heavy field infection and also significantly superior in yield over the remaining eight sub-strains. Moreover, other characters remaining the same, the latest selection of C. 520/9 has been found to be 17 per cent. finer than that of the previous year. It is fortunate that in C. 520/9 the Department of Agriculture, U. P., has got a type which possesses the characters of disease resistance, yield and quality. It can, therefore, be said without exaggeration that but for the above technique employed, the evolution of C. 520/9 would not have been possible. During the later stages of selection when there are several progenies of plants belonging to different families, compact family block system, (Hutchinson and Panse 1937), can be usefully adopted. By this means it is possible to isolate families which breed true and therefore can be immediately bulked up and released for distribution from those which do not and therefore still require further selection and purification.

THE SIGNIFICANCE OF SAPATOXIN AND C/N RATIO IN THE GROWING CORMS OF COLOCASIA*

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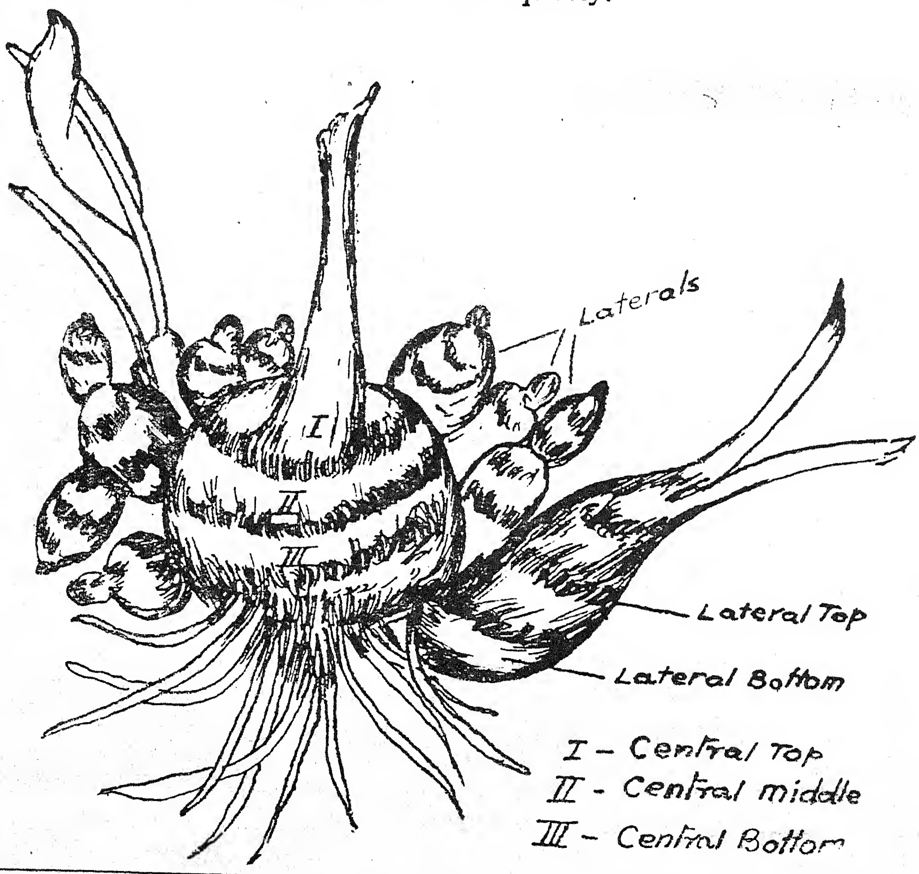
Multiplication in *Colocasia antiquorum* where one corm gives rise to another is apparently similar to yeast. Of the various corms thus produced, the layman most often discards the central (primary) one; while the agriculturist gets, if at all, a very small premium for that. It is then the lateral (secondary, tertiary, etc.,) corms which are generally utilized for vegetable products. Experience shows that unlike the laterals the central corm is a bit sharp and biting in taste even when cooked. It was, therefore, desired to estimate the percentage accomodation of some of the most important ingredients in several growing corms and thus to determine, partly if not wholly, the causal factor of differences in their quality.



* The work reported in this paper was carried out by the author in the Institute of Agricultural Research of the Benares Hindu University.

As usual, corms in most of the experimental plants were arranged in 4 to 5 groups round about the central. As shown in the accompanying diagram, both the central and the lateral corms in sequence were analysed for total carbohydrates (including total sugars and starch), total nitrogen and sapatoxin. But in the various groups, the values for each of these constituents resemble so closely, say, of secondary to secondary, and of tertiary to tertiary, that group to group presentation of data is considered unnecessary. The same is true for samples obtained from different plants grown for the purpose.

For estimation of total sugars and starch Yemm's (1925) modified Iodimetric method was adopted. Total nitrogen was estimated by the well known modified Kjeldahl method (Loomis and Shull, 1937). Sapatoxin was determined after Rosenthaler (1930), where o. 2 gms. of sample was dried in an oven at 110°C and was boiled three times with 100 cc. of water. The extract was concentrated to a small volume, treated with alcohol and filtered. The precipitate thus obtained was boiled repeatedly with dilute alcohol, the decoction was filtered when hot and mixed with the above filtrate. Later the alcohol was distilled off, the residue taken up with water, evaporated to a small bulk, and treated with a saturated solution of baryta. The saponin baryta was collected and dried on a tared, ashless filter paper in an oven at 110°C for three hours and finally in an air oven at 100°C to constant weight. Finally, the whole thing was ignited and from the mass of the residue ($BaCO_3$) the corresponding barium oxide was calculated and thus the weight was deducted from the amount of saponin baryta. The results of the analysis are presented in the following table.

Carbohydrate-nitrogen and sapatoxin percentage in growing corms (central and laterals) of *Colocasia antiquorum.*

Corm	Total Sugars	Starch	Total carbohydrates	Total nitrogen	C/N ratio	Sapatoxin
I Central (Primary) Top ..	1·9	21·2	23·0	2·11	10·9	5·5
,, Middle	1·4	20·8	22·2	1·42	15·6	7·5
,, Bottom	1·4	21·1	22 5	2 02	18·2	7·5
II. Laterals (Secondary) Top ..	1·7	20·5	22·2	2·02	10·9	6·5
,, Bottom	1·2	20·2	21·7	1·28	16·9	5·0
III. Laterals (Tertiary) ..	1·2	19·6	20·8	2·57	8·1	5·0
IV. ,, ,, ..	1·2	19·9	21·1	2·57	8·1	5·0
V. ,, ,, ..	1·2	19·6	20·8	2·57	8·1	5·0

It will be noted that the percentage of total sugars is relatively high in the primary corms which decreases towards the secondary and tertiary; so also is the case with starch content, and thus the percentage of total corbohydrates follows the same trend as the fractions. But unlike the behaviour of total carbohydrates and their components the percentage of total nitrogen is minimum in the primary corms, and then increased gradually towards the secondary and tertiary when ultimately it attains its maximum. Similar to these behaviour of total carbohydrate and its components, the C/N is very high in the primary corms but wanes out towards the laterals. The percentage of starch of primary laterals is fairly low whereas the percentage of nitrogen is very high.

These results of analysis suggest that growing regions of the corms of colocasia which emerge out from the primary one which is the store house of food materials, mainly in the form of starch, contain less amount of total carbohydrate and sapatoxin but more of total nitrogen. This is probably because the primary corm which is attached to the aerial shoot accumulates more of carbohydrates which are products of photosynthesis and therefore directly come from the manufacturing machinery. The carbohydrates are gradually deported to the secondary and tertiary. Because of this mechanism of translocation the lateral corms lack in carbohydrate but are rich in nitrogen. So also the same phenomenon takes place with the sapatoxin which is a toxic substance (Allen, 1930).

Thus, it can be concluded that lateral corms which are preferred for vegetable purposes are much superior to the primary corms, because :—

1. The laterals are high in nitrogen (*i.e.* protein).
2. The laterals contain less amount of sapatoxin—a toxic substance.
3. The laterals are of good quality.

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MANURES AND MANURING

By Sudhir Chowdhury

Chapter IV

FERMENTATION OF FARM MANURES

The urine of healthy animals when it is voided, is either sterile or essentially germ-free. Its infection, however, results immediately upon being voided and being a good medium for promoting bacterial growth, it is soon teeming with millions of living forms But the solid excrement of all kinds of farm animals when it is voided is already swarming with micro-organisms. Wuterich and von Freudenreich examined the fresh dung of two cows fed on grass and found that in one case the number present in a gram of dung was 10 and 12¼ millions respectively on two separate days, in the other the numbers were 1·8 and 4 millions on the same days. Later after feeding the same animals with hay the number of the bacteria in the dung rose in the case of one cow to 187 millions, and in the other to 387 millions per gram. In the dung of cows kept in the stall, Guper found from 1,000,000 to 120,000,000 of organisms per gram in contrast to but from 1,000,000 to 4,000,000 when they were in pasture. In comparisons of the fæces of cattle and horses, Stoklasa found in a gram of the former 60,000,000 to 90,000,000 of micro-organisms and in the same quantity of the latter, from 100,000,000 to 150,000,000. The numbers found by Savage in the dung of the three horses examined was from 1½ to 2 millions, in four cows from 1 to 10 millions, and in three pigs examined the solid excreta contained 10 to 100 millions per gram.

The number of micro-organisms in straw litter has been found to range from 10,000,000 to 400,000,000 per gram. In peat used for litter Bachhaus and Cronheim have reported from 2,000,000 to 3,250,000 of micro-organisms per gram.

The numbers of Bacteria Decrease Gradually :

Mixtures consisting of litter and of solid and liquid excrement are exceedingly rich in living organisms although their numbers finally show a decrease. In manures 14 years' old, which had remained without chemical treatment and which had shrunk greatly in volume, there were found 12,500,000 micro-organisms per gram whereas in identical material which had been treated with kainit and gypsum residue from the manufacture of double superphosphate, but 3,750,000 micro-organisms were found per gram of manure.

Types of Micro-organisms Present in Manures :

(1) *Bacteria.*—The most characteristic bacterium present in specially large numbers in the intestines and in the fresh fæces of all

kinds of animals is *Bact. coli*, of which there are several very slightly modified forms differing in their power of fermenting carbohydrates. Wuterich and von Freudenreich found *Bact. coli* chiefly in the fæces of cows along with a smaller number of *Bs. subtilis* and *Bact. Schafferi.* Savage found many *streptococci* as well as *Bact. coli* in the fæces of farm animals, together with the spores of *Bs. enteritidis sporogenes*, the latter being especially abundant in fresh pig dung. Heinick showed that the excreta from pigs often contains *Bact. lactis aerogenes*, as well as *B. coli*, and large numbers of the former organism have been found in the intestinal canal and fæces of other animals also.

Sewerin isolated from horse-dung thirty-two species or varieties, the majority of which in manure one month old were rod-shaped organisms. *Cocci* were comparatively uncommon until the manure had been stored three months. In stable manure at 60° to 70° C, Dupont found *B. mesentericus ruber*, but chiefly *B. thermophilus grignoni.* In an old sample of stable manure Lohnis and Kunze found forms of *Proteus* and the uro-bacteria most abundant with large numbers of *Bact. fluorescens* (liquifying and non-liquifying forms) as well as *Bact. putidum*, *Bs. mesentericus*, *Bs. subtilis* and many denitrifiers were isolated also.

The bacteria mentioned may be considered natural inhabitants of the digestive tract; others are introduced in the food, and under certain circumstances may live and increase in number within the animal and be found in the dung. A number of species also gain access to the manure while it is in the barn and farmyard and multiply rapidly in it, the mixture of solid and liquid excreta proving an excellent nutrient medium for them. Some of the kinds are introduced in the litter and the fodder, others are conveyed by the dust in the air and the water used about the premises.

(2) *Actinomycetes.*—The *actinomycetes* are also found in the farm manures, certain of which are capable of enduring high temperatures, and others such as the 'strahlenpilze' are of importance in connection with the formation and decomposition of humus substances.

(3) *The Yeasts.*—Among the *yeasts* the *Monilia* species and *Torulaceae* and even the true *Saccharomycetes* are present.

(4) *The Moulds and other Organisms.*—The moulds often develop in manure to a serious extent; at least *Oidium lactis* passes readily through the digestive tract uninjured in which respect it differs widely from the yeasts. The moulds are powerful destroyers of both nitrogenous and non-nitrogenous constituents of manure. This is especially true of very dry horse and sheep manure. In the former their growth is the chief cause of the phenomenon known as 'fire-fanging'.

Other organisms which occasionally develop upon fermented manures in storage, but which are of relatively less agricultural importance of the *myxomycetes*.

Destructive Changes in the Non-nitrogenous Matter :

In the process of decomposition taking place in animal manures, fats and carbohydrates are destroyed in large quantities. The loss of these substances is rarely, if ever, less than 10 per cent and is often excess of 50 per cent.

Certain earlier investigators were inclined to the belief that the chief loss of carbohydrates during the fermentation of animal manures was confined to the cellulose; yet more recent investigations by Miller show that 21.7 per cent of the original sugar was lost, also 18.6 per cent of the original pentosans, and but 8.7 per cent of the original cellulose. It was observed by Sjollema and De Ruyter de Wild, that at a temperature of 35° C., under anaerobic conditions, the pentosans suffered heavy losses; however, they remark that this fact enhances greatly the final value of the manure.

According to Schloesing organic matter loses more carbon than oxygen but the hydrogen content remains unchanged when organic matter decomposes under exclusion of air.

The majority of the aerobic and anaerobic organisms present in animal manures, have to do with the decomposition of the carbohydrates. Prominent among these are the aerobicter amylobacter groups which give rise to the volatile and non-volatile fatty acids and to extensive gas production, the latter of which represents material losses of vegetable matter.

(1) *Decomposition of Starch*.—Starch is transformed by *B. mesentericus ruber* into carbon dioxide, formic acid, and valerianic acid; also sugar into carbon dioxide, acetic acid and butyric acid. *B. sanveolens* transforms starch into sugar, dextrin, alcohol, aldehyde, formic acid, acetic acid, and butyric acid. The action of the butyric acid bacteria upon starch has been found to result in the production of small quantities of ethyl alcohol, 35 per cent of butyric acid and 9 per cent of acetic acid. This action, however, depends upon varying conditions and certain members of this group may even fail to attack starch at all.

(2) *Decomposition of Pectin* :—Among the organisms effecting the destruction of the pectin of straw and manure may be mentioned the aerobic form *B. mesentericus ruber*. The organisms chiefly responsible for the destruction of pectin are nevertheless aided by high temperatures and exclusion of air.

(3) *Decomposition of Cellulose* :—Cellulose appears to be capable of destruction by anaerobic organisms, denitrifying bacteria,

and also by certain aerobic bacteria and moulds. In the upper well-aerated parts of the heap complete oxidation occurs, and carbon dioxide and water are the end products cf the change; but in the interior where anaerobic conditions prevail, methane, hydrogen and carbon dioxide and other substances are formed. Deherain and Dupont made analyses of the gases within a large heap of mixed farm manure. Below are some of the results :—

	Temp.	CO_2	CH_4	H	N	O
August 24, 1899						
Top of the Heap ...	71°C	50	17.4	3.1	29.5	0
Middle of the Heap ...	67°C	68	23.9	7.4	0.7	0
Bottom of the Heap ...	63°C	49	40.8	3.9	6.0	0
September 20, 1899						
Top of the Heap ...	66°C	42.7	52.4	0	9.8	1.1
Middle of the Heap ...	65°C	49.5	48.3	0	2.2	0
Bottom of the Heap ...	52°C	47.8	51.2	0	1.0	0

Experiments of Omelianski and of Van Senus show that organisms of the group of *B. amylobacter* destroy cellulose at least only whenr it is present in amounts not in excess of one per cent. In such cases several of the fatty acids are formed, together with traces of highee alcohols and other substances but the gases consisted of carbon dioxidn and hydrogen, while methane was entirely lacking. This hydroge-fermentation is, therefore, different from the methane fermentation pro duced by *B. methanigenes*, yet both acetic acid and n-butyric acid are produced by the latter. Whether the methane fermentation or the hydrogen fermentation shall dominate seems to depend upon the existent conditions but usually the methane fermentation is the first to develop. Both sets of organisms are, however, present in the intestinal tract of domestic animals and are therefore found in the dung when voided. It appears probable from the experiments with either materials that the methane fermentation may take place more rapidly in a neutral than in an alkaline medium. It is also probable that in open, strongly heated manure certain thermophilic decomposers of cellulose may be present.

(4) *Decomposition of Fats and Waxes* :—It appears probable that some of them may under certain circumstances undergo at least a partial breaking up by anaerobic organisms. Their destruction, which takes place readily in the presence of oxygen is quickly affected

by exclusion of air. The glycerine which is produced as a result of the process is itself quickly destroyed. This destruction may be caused by *B. boocopricus*, an organism present in cow-dung and give rise to methyl alcohol and butyric, acetic and formic acids. In any event, the decomposition of the fats and waxes in the manure when it is properly stored, takes place too slowly to have any great practical significance.

The Ammoniacal Fermentation of Urine :

Freshly excreted urine of man is slightly acid due to the presence in it of acid sodium phosphate, that of most herbivorous animals being neutral or slightly alkaline. However, on being exposed to the air for a few hours the urine of all the animals becomes very strongly alkaline and develops an odour of ammonia which is often prevalent in cow-sheds and stables. The urea, uric acid and hippuric acid, also undergo fermentation with the production of ammonium carbonate from which gaseous ammonia is set free.

(1) *Decomposition of Urea* :—One of the first changes taking place in urine is the breaking up of the urea into ammonium carbonate and this finally into ammonia, carbon dioxide and water as indicated below :—

$$CO(NH_2)_2 \; 2H_2O — (NH_4)_2CO_3$$
$$(NH_4)_2CO_3 — 2NH_3 + CO_2 + H_2O$$

This transformation of urea is usually practically completed in manure piles in from four to five days.

A number of different species of bacteria usually spoken of as 'urobacteria' are capable of effecting this change. They are very widely distributed in the air, in dirty water, in dust and soil and in manure heaps. Some of them are *coccus* forms while others are *bacilli*, the latter appear to prevail in soil. All are aerobic and grow best at a temperature of 30° to 32° C in 2 to 5 per cent. solutions of urea made slightly alkaline by adding 0.2 per cent of ammonium carbonate. A number of species form spores which resist the temperature of 95° to 100° C for an hour or more ; others do not produce spores and are easily destroyed by heating to 70° C for a short time. They differ very considerably in their power of hydrolysing urea. *Urobacillus Pasteurii* under favourable conditions at 30°C is able to decompose 3 gms. per litre per hour, while many of the *urococci* are only able to ferment this amount in twenty-four hours.

The mass of bacteria required to transform a given quantity of urea is surprisingly small, since Miquel has shown that one part by weight of a culture of *Urobacillus duclauxii* was capable of changing 4000 parts of urea into ammonia and Burchard in experiments with *Microc. ureae liquefaciens* found it capable of transforming urea into ammonia to the extent of from 180 to 1200 times its own weight.

(2) *Decomposition of Uric and Hippuric Acids.*—" Comparatively little is known of the bacterial decomposition of uric and hippuric acids. The nitrogen in both appears to become changed into ammonium compounds, but the stages of the process and the organisms connected in it are very imperfectly known. In some experiments carried out by F. and L. Sestini, a solution of uric acid infected with decomposing urine and exposed to the air was changed into ammonium bi-carbonate and carbon dioxide, and Gerard showed later that some organisms hydrolyse the compound into urea and tartronic acid, the former being acted upon later by the uro-bacteria and changed into ammonium carbonate.

" Hippuric acid can be converted by acids and alkalis into its constituents benzoic acid and glycocoll (amino-acetic acid), and van Tieghem states that the same change can be induced by *Urococcus ureae.* Burri considers that calcium hippurate is fermented by certain bacteria with the production of ammonium carbonate and Schellmann isolated a number of organisms from sewage and soil which broke down hippuric acid and glycocoll to compounds of ammonia, but not much is known of their morphology or relationship."

Putrefaction and Decay:

Although a large amount of the protein substances, present in the food of an animal is digested and absorbed from the intestinal tract, some remains and passes out in the faeces, either little changed or broken down to a considerable extent into simple compounds. Further decomposition of the nitrogenous organic matter of the manure, consisting largely of the proteins begins with either one of two processes—decay or putrefaction. Decay is produced by aerobic bacteria, and naturally occurs when the conditions are most favourable for their development. When the conditions are otherwise, the growth of these bacteria is checked, and their further decomposition would be extremely slow were it not for the other process—putrefaction. Putrefaction is the rapid decomposition of the proteins, accompanied by the evolution of evil smelling gases. It is produced by anaerobic bacteria. In the same manure pile decay and putrefaction may be in progress simultaneously, decay taking place on the outside, while putrefaction occurs in the interior where the supply of oxygen is limited. By means of the two processes decomposition is greatly facilitated.

Decay produces a very rapid and complete decomposition of the substance in which it operates, most of the carbon and hydrogen being quickly converted into carbon dioxide and water and the nitrogen into ammonia and probably into some free nitrogen.

Putrefaction results in a large number of complex intermediate compounds and proceeds much more slowly. Many of the substances thus produced are highly poisonous and most of them have a very offensive odour. They may be further broken down by decay when the conditions are suitable, or by a continuation of the process of putrefaction. In either case the poisonous properties and the odour are removed.

Putrefaction is carried on by a large number of forms of bacteria, the resulting product depending on the substance in process of decomposition and on the bacteria involved Some of the characteristic, although not constant products formed in the putrefaction of albumin and proteins are albumoses, peptones and amino-acids, followed by the formation of cadaverine, putrescine, skatol and indol. The unpleasant odour of faeces is due to skatol and indol. Where an abundant supply of oxygen is present, or where sufficient supply of carbohydrates exist these substances are not formed. There are many other products of putrefaction, including a number of gases, as carbon dioxide, sulphuretted hydrogen, methane, phosphine, hydrogen, nitrogen and the like.

It will be noticed that these. changes, like those occurring in the non-nitrogenous organic matter, involve a breaking down of the more complex compounds and the formation of simpler ones, and that a very large number of bacteria are concerned in the various steps, while even the same substance may be decomposed and the same resulting compounds formed by a number of different species of bacteria. The chief of the bacteria concerned are *Bact. vulgare*, *Bact. Zopfii*, *Bact. coli*, *Bact. lactis aerogenes* and *Bact. fluorescens liquefaciens.*

Ammonification of Solid Manure and Litter:

Decay and putrefaction may be considered as the beginning of the process of ammonification. Ammonification as its name implies, is that stage of the process during which ammonia is formed from the intermediate products

Like the other processes of decomposition, there are many species of bacteria capable of forming ammonia from nitrogenous organic substances, the chief among which are *B. mycoides, B. subtilis, B. mesentericus vulgatus*, *B. janthinus* and *B. proteus vulgaris.* But different species display different abilities in converting nitrogen of the same organic meterial into ammonia, some acting more rapidly and more thoroughly than others.

Under the conditions accompanying the usual normal fermentation of farm manure the quantity of ammonia actually produced from the nitrogenous substances of the solid excrement and of the litter is very small. It has been shown repeatedly that a condition most favourable to the formation of ammonia from such substances is the exclusion of air. In an experiment by Jentys only

one per cent of the nitrogen of solid excrement was changed into ammonia in the course of one month under free access of air, but in an artificial atmosphere of nitrogen 11 per cent of nitrogen was changed into ammonia in the same period of time. In experiments with a mixture of manure and straw, Dietzell found that but 3 per cent of the nitrogen was changed into ammonia at the end of six months in case care was taken to secure good aeration, but that under exclusion of air about 20 per cent of the nitrogen had been changed into ammonia. The conditions, therefore, best suited to the formation of ammonia from urea are, according to the authorities just mentioned, quite the opposite of those essential to the production of ammonia from the solid excrement. On this point, however, Deherain and Dupont disagree with the other investigators for they hold that under anaerobic conditions the transformation of the albuminoid substances of the solid excrement and of the litter into ammonia is very slight, and that it takes place far more readily in the presence of air.

The reasons for the slowness of the formation of ammonia in the solid excrement are made perhaps more appreciable when one recalls that it is composed to the extent of one-half of its nitrogen content, of the materials which have already resisted the action of the digestive ferments of the stomach or stomachs and of the intestines and that approximately the other half of the nitrogen is in the bacteria and other lower organisms voided with the manure. The importance of this point is further emphasized by the fact that the organisms mentioned are rich in nuclein compounds and in chitin, all of which are highly resistant to decomposition. Furthermore, the entienzymes present in the living organisms afford a certain resistance to their decomposition and destruction even for a considerable time after their life functions have ceased.

Nitrification in Manure Heaps:

Under ordinary conditions little nitrification occurs in the manure heap except perhaps in the outer layers, and it is not until the manure has become incorporated with the soil that its nitrogenous compounds become rapidly changed into nitrates. This is owing to the inhibiting action of the excess of organic material present and the want of good aeration in the manure heap.

The transformation of nitrogen does not stop with its conversion into ammonia, but goes on by an oxidation process to the formation of first nitrous and then nitric acids. This may be considered to proceed according to the following equations :

$$2\,NH + 3\,O_2 \ldots\ldots 2HNO^2 + 2H_2O$$
$$2HNO_2^2 + O^2 \ldots\ldots 2HNO_3$$

The acid in either case combines with one of the bases of the soil, sodium, magnesium or calcium, usually calcium.

Each of these steps is brought about by a distinct bacterium, but the bacteria are closely related. *Nitrosomonas* are the bacteria concerned in the conversion of ammonia into nitrous acid or nitrites. Associated with the nitrite organisms in the soil are the nitrate bacteria, which oxidise the nitrites into nitrates. They are non-motile rod-shaped bacteria, about 1 μ long, 0·3 to 0·4 μ broad, and are included in the genus *Nitrobacter*. In nature both groups of organisms are associated and live together. They are abundant in well and river water, and are distributed through the upper layers of the soil, being most abundant from 4 to 9 inches below the surface, and not usually found at a greater depth than 18 or 20 inches. Under the conditions which prevail in the soil, however, only nitrates—the end products of their combined action—can be detected, the nitrites which are formed being immediately oxidised as fast as they are produced; the two organisms appear to act symbiotically and simultaneously.

Certain conditions are essential for the nitrification process besides the presence of ammonium salts and the specific nitrifying bacteria. The chief of these are an adequate temperature and suitable degree of moisture, abundant free oxygen and carbon dioxide, a basic substance, such as calcium or magnesium carbonate, darkness and the absence of soluble organic matter and free ammonia.

Denitrification :

The nitrogen-transforming bacteria thus far studied have been those that cause the oxidation of nitrogen as the result of their activities. A number of forms of bacteria that accomplish a reverse action may now be considered. The several processes involved are commonly designated by the general term denitrification, and comprise the following :

(1) the presence of certain species of bacteria,

(2) a supply of nitrates,

(3) a considerable amount of easily assimilated organic substance,

(4) total absence or a very limited access of free oxygen.

These, it will be noticed, are practically opposite conditions to those required for nitrification. The exclusion of any one of them checks denitrification. A large number of kinds of bacteria have been isolated which are capable of decomposing nitrates with the evolution of free nitrogen. Many of them are found in water and in the soil. They are also especially abundant upon straw and in the dung of the horse, cow and other herbivorous animals; in faeces of man and carnivorous animals they are rarely present. The number of organisms that possess the ability to accomplish denitrification is very large, in fact, greater than the number involved in the oxidation process.

Some of the specific bacteria reported as bringing about nitrate reduction are : *B. ramosus* and *B. pestifer* ; which reduce nitrates ; B. *mycoides* *B. subtilis*, *B. mesentericus vulgatus* and many other ammonification bacteria which are capable of converting nitrates into ammonia.

B. denitrificans alpha and *B. denitrificans beta* :—Reduce nitrates with the evolution of gaseous nitrogen.

In manure and compost heaps there is little or no denitrification with its consequent loss of nitrogen in the gaseous form, since the necessary nitrates are generally missing, the excess of soluble organic matter and absence of aeration preventing their formation except in the upper layers of the heaps. In well-aerated composts, however, and in farmyard manure loosely put together, nitrification may occur and be followed by denitrification when the heaps become saturated with water through exposure to heavy rains.

Conditions Influencing the Fermentation of Farm Manures :

The rotting of all classes of farm manures is a consequence of exposure to the air and the action of bacteria or other micro-organisms whose growth in the manure causes fermentation. The rotting of manure is affected both as regards the rate at which it takes place and the nature and the results of the fermentations which follow in it by varying conditions Most important among these are :

(1) *Temperature* : The higher the temperature the more rapid the fermentation and the greater the danger of loss of valuable constituents.

(2) *Degree of Compactness of the Heap* : Fermentation goes on more rapidly in proportion as the mass is light and open so that the air gains free access to all parts of it. The effect of exposing the manure to the action of the air is to induce the development of the aerobic type of organism and thus to promote more rapid fermentation. On the other hand, if the manure be compact, the slower but more regular the fermentation due to the anaerobic type of organism. Fermentation takes place more slowly and the temperatures are lower in proportion as the manure is compact. It must be remembered that in the proper rotting of farm manures both kinds of fermentation should be fostered. It is, in fact, on the careful regulation of the two classes of fermentation that the successful rotting of the manure depends.

(3) *Dampness of the Manure Heap* :—Water in manure, as in soils, tend to lower the temperature and thus to retard or preveut fermentation. It also in part excludes the air or limits the supply of atmospheric oxygen, thus preventing aerobic fermentation. The rate of fermentation, therefore, can be controlled to

a considerable extent by the free use of water. If a heap of manure is found to be exclusively hot, the addition of water especially, if accompanied by trampling will check the too rapid fermentation.

(4) *Composition of the Manure*:—The rate at which fermentation will take place in manure depends under otherwise similar conditions very largely on the percentage of soluble nitrogenous matter it contains. The greater the proportion of soluble nitrogen containing compounds, the more rapid the fermentation This more rapid fermentation in the case of manures containing abundant soluble nitrogenous matter is chiefly due to the fact that such material serves as food for the micro-organisms causing fermentation. The soluble nitrogen compounds named are found chiefly in urine, hence it follows that when the urine is all saved and carefully mixed with the manure, fermentation goes on more rapidly than under other conditions.

Change of the Bulk and Composition of Rotting Manure :

Because of the great loss of carbon dioxide during the fermentation processes, there is a considerable change in bulk of the manure. Fresh excrement loses 20 per cent in bulk by partial rotting, 40 per cent by more thorough rotting, and 60 per cent by becoming completely decomposed. This means that 1000 pounds of fresh manure may be reduced to 800, 600, or 400 pounds, according to the degree of change it has undergone.

Although considerable loss of nitrogen may have occurred through aerobic bacterial action, and although both nitrogen and the minerals may have been considerably leached away, the loss of carbon dioxide is so much greater that generally there is an actual percentage increase of the former constituent in the well-rotted product. This relation is well shown by figures from Wolff, in which the samples were compared on the bases of equal amounts of dry matter :

Composition of Fresh and Decomposed Manure.

——	Fresh Per cent.	Rotted Per cent.
Ash	3.81	4.76
Nitrogen	0.39	0.49
Potash	0.45	0.56
Lime	0.49	0.61
Magnesia	0.12	0.15
Phosphoric Acid	0.18	0.23
Sulphuric Acid	0.10	0.13

It must be remembered, however, that this is only a general case and holds good only when the manure has had fairly careful attention. When the manure has been improperly handled, the soluble constituents may be lost as soon as formed and a rotted product may result which is very low in nitrogen, potassium and phosphorus. It is, therefore, evident that the handling of the fresh manure is a controlling factor in the ultimate value of the product.

A further insight into the condition of rotted manure is given by Voelcker, the data being calculated to a dry weight basis :

——	Fresh Manure Per cent.	Rotted Manure Per cent.
Soluble organic matter	7.33	15.09
Soluble inorganic matter	4.55	5.93
Insoluble organic matter	76.14	51.34
Insoluble inorganic matter	11.98	27.59

These figures show the increased soluble matter in well decomposed manure and emphasized the value of rotting. The great loss of organic matter through the giving off of carbon dioxide is also evident.

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MONTHLY AGRICULTURAL REPORT

DEPARTMENT OF AGRICULTURE, UNITED PROVINCES

October, 1943.

I. Season.—There was no rain during this month except for light showers in the third week in all the districts other than those comprising the Meerut, Agra and Rohilkhand Divisions. The total rainfall for the month was in defect of the normal in almost all the districts.

II. Agricultural operations.—Harvesting, reaping and threshing of *kharif* crops and preparation of land for *rabi* crops continue. Picking of cotton is in progress. *Rabi* crops are being sown. Late paddy and sugarcane are being irrigated. Crushing of early varieties of sugarcane has commenced in some western districts.

III. Standing crops and IV. Prospects of the harvest.—Except in low-lying areas where water-logging has occurred and in areas affected by floods, the standing crops are reported to be in a healthy condition. The clear weather which continued to prevail during the month, interspersed by light showers during the third week, has produced a beneficial effect on late paddy and sugarcane. The prospects of outturn are favourable.

V. Damage to crops.—No report of damage to standing crops during the month has been received from any district.

VI. Agricultural stock.—Although reports of cattle diseases have been received from a number of districts, the condition of agricultural stock is reported in general to be satisfactory. In Table 1, prepared from data furnished by the Director of Veterinary Services, United Provinces, are shown the figures for the number of seizures, deaths and mortality from infectious cattle diseases during this and the previous months. It would appear from this table that there has been, since last month, a marked decrease both in the total number of seizures as well as deaths, but a slight increase in mortality. The number of seizures and deaths from Anthrax show a pronounced decrease, although mortality has remained 100 per cent. In the case of Hæmorrhagic Septicæmia, there has been a pronounced decrease both in the number of seizures as well as deaths, but a slight increase in mortality. There has been a decrease in the number of seizures and deaths from Blackquarter, but a considerable increase in mortality. In the case of Rinderpest, there has been an increase in the number of seizures, deaths and mortality. There has been a marked decrease in the number of seizures, and deaths from foot and mouth disease, but an increase in mortality. In the case of "Other Diseases," there has been a marked increase in the number of seizures, deaths and mortality :

TABLE 1

Number of seizures, deaths and mortality from infectious cattle diseases in September and Octber, 1943.

Diseases	Seizures		Deaths		Mortality	
	September	October	September	October	September	October
Anthrax	16	8	16	8	100	100
Hæmorrhagic Septicæmia ...	2,388	562	1,885	456	79	82
Blackquarter	76	40	42	32	55	80
Rinderpest	1,239	1,390	707	812	57	58
Foot and mouth ...	10,406	4,626	52	32	0·50	0·69
Other diseases ...	28	91	..	14	..	15
Total ...	14,153	6,717	2,702	1,354	19	20

N.B.—Mortality$=\frac{\text{No. of deaths}}{\text{No. of seizures}}\times 100$

VII. Pasturage and fodder.—Pasturage and fodder are reported to be sufficient in almost every district.

VIII. Trade and prices.—In Table 2 are shown the retail prices in rupees per maund of important agricultural commodities at the end of this and the previous months. It would appear from this table that except for a slight rise in the price of rice and arhar dal, the prices of all other commodities have remained more or less stationary with a slight tendency to fall :

TABLE 2

Retail Prices in rupees per maund of agricultural commodities for September and October, 1943

Commodities	Retail prices	
	September	October
Rice	18·646	19·044
Wheat	14·318	14·173
Barley	10·306	10·24
Gram	11·214	11·164
Arhar Dal	14·788	15·352

IX. Health and labour in rural areas.—Cases of malaria, cholera and small-pox have been reported during the month. October being an important month for the preparation of land and for the

sowing of *rabi* crops, the fairly high incidence of malaria has hindered these operations. Otherwise the health in rural areas has been generally satisfactory.

November, 1943

I. Season.—During this month, there was no rain in any district.

II. Agricultural Operations.—Harvesting of early *kharif* crops had finished in almost all the districts and that of late paddy is in progress. Sugarcane is being harvested and crushed for *gur* and factory sugar. *Rabi* crops such as peas are being sown and those already sown are being irrigated. Picking of cotton is nearing completion.

III. Standing Crops and IV. Prospects of the Harvest.—The growth of the *rabi* crops already sown is reported to be satisfactory except in some dry areas where the need for rain is being felt. The prospects of outturn of the late paddy and sugarcane crops are favourable except in some low lying areas where damage to cane has occurred from water-logging.

V. Damage to Crops.—There has been no damage to standing crops except some in the Kheri District from floods caused by a breach in the Sarda Canal.

VI. Agricultural Stock.—Although cattle diseases have been reported from several districts, the condition of agricultural stock is generally satisfactory. In Table 1, compiled from data supplied by the Director of Veterinary Services, United Provinces, are given the figures for the number of seizures, deaths and mortality from infectious cattle diseases during this and the previous months. It would appear from this table that there has been, since last month, a marked decrease both in the total number of seizures as well as deaths, but a slight increase in mortality. There has been only one case of seizure and death from Anthrax as against eight cases of seizures and deaths during the previous month. The number of seizures and deaths from Hæmorrhagic Septicæmia show a highly marked decrease, although there has been an increase in mortality. No case of seizure and death from Black-quarter has been reported during the month. As regards Rinderpest, there has been a pronounced decrease both in the number of seizures as well as deaths, but an increase in mortality. In the case of Foot and Mouth disease, there has been a considerable decrease in the number of seizures but only a slight decrease in the number of deaths, resulting in an increase in mortality. There has been a decrease in the number of seizures and deaths from "other Diseases" but an increase in mortality.

Table No. 1.

Number of Seizures, Deaths and Mortality from Infectious Cattle Diseases in October and November, 1943.

Diseases	Seizures		Deaths		Mortal ty	
	October	November	October	November	October	November
Anthrax ..	8	1	8	1	100	100
Hæmorrhagic Septicæmia	562	155	456	131	81	85
Blackquarter ..	40	..	32	..	90	
Rinderpest	1,390	724	812	492	58	68
Foot and Mouth ..	4,626	2,205	32	30	0·69	1·4
Other Diseases ..	91	47	14	10	15	21
Total ..	6,717	3,132	1,354	664	20	21

N. B.—Mortality$=\frac{\text{No. of Deaths}}{\text{No. of Seizures}} \times 100$

VII. Pasturage and Fodder.—Pasturage and fodder are reported to be sufficient in all the districts other than the Farrukhabad, Fatehpur and Unao Districts where some scarcity is reported.

VIII. Trade and Prices.—Table 2 gives the retail prices in rupees per maund of important agricultural commodities at the end of this and the previous months. There has been a general decrease in the prices of all commodities:

Table 2.

Retail Prices in Rupees per maund of Agricultural Commodities for October, and November, 1943.

Commodities.	Retail Prices.	
	October	November
Rice	19·044	17·680
Wheat	14·173	13·388
Barley	10·247	9·121
Gram	11·164	10·510
Arhar Dal	15.352	14·914

IX. Health and Labour in Rural Areas.—Except in the Pilibhit District where cholera broke out in an epidemic form during this month, the health of the agricultural and labouring population in rural areas has been generally satisfactory. Cases of cholera, malaria and small-pox have been reported from a few of the other districts.

December, 1944.

I. Season.—Except for light showers in the Dehra Dun, Saharanpur and Garhwal Districts, there was no rain during this month in any district.

II. Agricultural Operations.—Harvesting of late paddy and sowing of *rabi* crops are nearly finished in almost all the districts. Crushing of sugarcane for *gur* and factory sugar is in progress *Rabi* crops are being irrigated. Preparation of land for sugarcane has commenced in some districts.

III. Standing Crops and *IV Prospects of the Harvest.*—Although the condition of the standing crops is on the whole satisfactory so far, need of rain is being urgently felt in a number of districts. In some areas, crops are reported to have been somewhat adversely affected for want of rain. The prospects of the harvest are largely dependent on the character of rainfall in the immediate future. In accordance with the reports received from District Officers, the average anna condition of sugarcane for the province is estimated at 14·6 (16 annas denoting a normal crop), or 91 per cent. of the normal.

V. Damage to Crops.—No damage to crops is reported except some from the Rae Bareli District caused by a breach in the local canal.

VI. Agricultural Stock.—The conditon of agricultural stock is reported to be generally satisfactory although cattle diseases have been reported from a number of districts. The figures for the number of seizures, deaths and mortality from infectious cattle diseases during this and the preceding months are shown in Table 1, which has been prepared from data supplied by the Director of Veterinary Services, United Provinces. It would appear from this table that there has been, since the last month, a considerable increase in the total number of seizures, but a marked decrease in the total number of deaths, resulting in a pronounced decrease in mortality. The number of seizures and deaths from Anthrax are much higher than those in the preceding month, the mortality having remained 100 per cent. In the case of Hæmorrhagic Septicæmia, there has been a general fall in the number of seizures, deaths and mortality. As in the previous month, in this month also, no cases of seizures and deaths from Black-quarter have been reported. As regards Rinderpest, there has been a considerable decrease in the number of seizures, death and mortality. There has been a pronounced increase in the number of seizures from Foot and Mouth disease, but a decrease in the number of deaths, giving a considerable decrease in mortality. The number of seizures, deaths and mortality from "Other Diseases" show a highly pronounced increase.

TABLE 1.

November of seizures, deaths and mortality from Infectious Cattle Diseases in Number and December, 1943.

Diseases		Seizures		Deaths		Mortality	
		November	December	November	December	November	December
Anthrax	...	1	9	1	9	100	100
Hæmorrhagic Septicæmia	...	155	89	131	72	85	81
Blackquarter	...	..	...	...	..	...	..
Rinderpest	...	724	577	492	324	68	56
Foot and Mouth	...	2,205	3,967	30	20	1·4	0·5
Other Diseases	...	47	101	10	44	21	44
Total	...	3,132	4,743	664	469	21	10

N. B.— Mortality $= \frac{\text{No. of deaths}}{\text{No. of seizures}} \times 100.$

VII. Pasturages and Fodder.—Pasturage and fodder are reported to be adequate in all the districts other than the Farrukhabad, Ballia, Unao and Hardoi districts where some scarcity is reported.

VIII. Trade and Prices.—In Table 2 are shown the average retail prices in rupees per maund of important agricultural commodities at the end of this and the preceding months. A general fall in the prices of all the commodities is noticed which is particularly marked in the case of rice.

TABLE 2.

Retail prices in rupees per maund of Agricultural commodities for November and December 1943.

Commodities	Retail prices	
	November	December
Rice	17·680	16·601
Wheat	13·388	12·599
Barley	9 121	8 679
Gram	10 510	10 056
Arhar Dal	14 914	14·218

IX. Health and Labour in Rural Areas.—The health of the agricultural and labouring population in rural areas has been generally satisfactory, although cases of cholera and small-pox have been reported from some districts.

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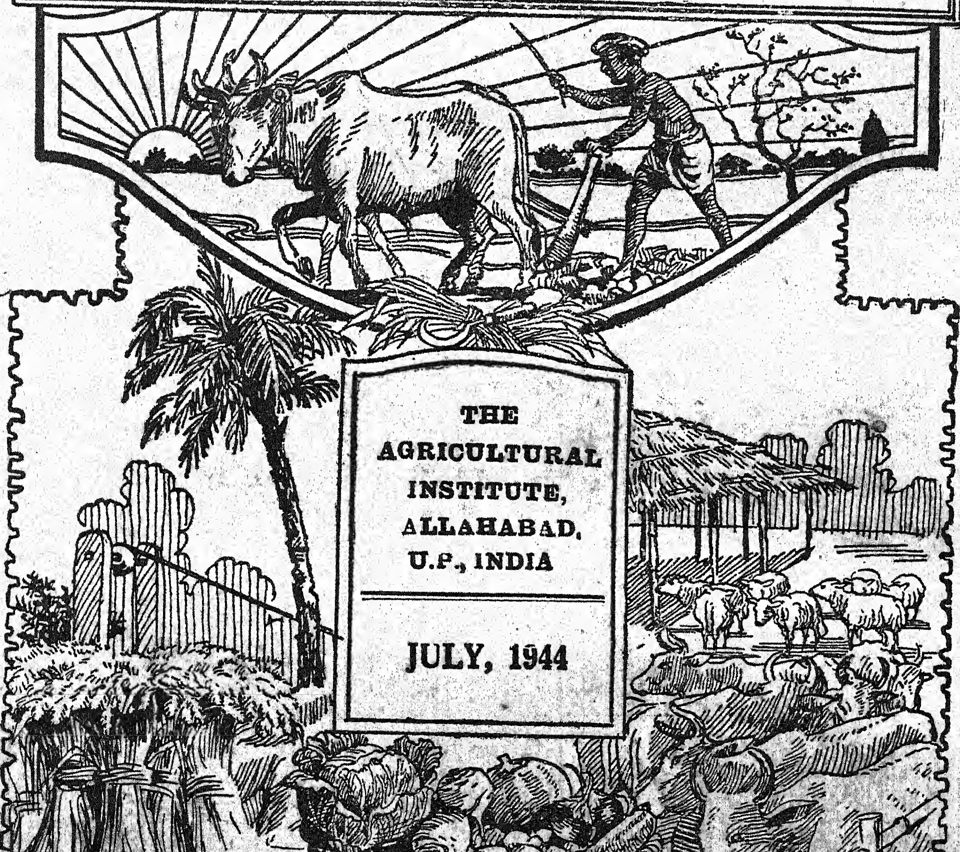

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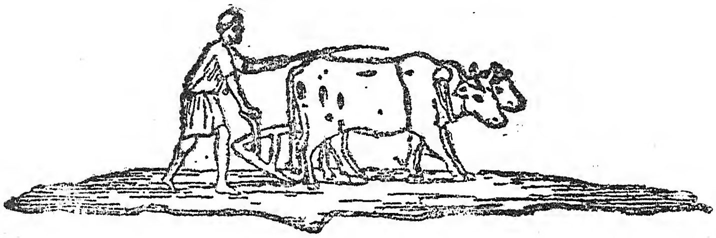

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PRINCIPLES OF PLANT PATHOLOGY

BY

SUDHIR CHOWDHURY

Chapter I

INTRODUCTION

Mycology is the science or study of fungi. Bacteriology is the science or study of the bacteria. Plant Pathology or *Phytopathology* is that branch of biological science which treats of the diseases of plants.

From the earliest times domesticated varieties of plants grown for food or for economic purposes have been subject to the attacks of diseases and early references to the terms 'blight' and 'blasting' show that they obtruded themselves on the mind of the cultivator long before their true nature was known. In Greek literature we find references to plant diseases in the writings of Aristotle, and more particularly in those of his pupil Theophrastus, the father of Botany. The latter describes diseases of a number of cultivated crops such as the various legumes, cereals, fig, olive, etc. Among Roman writers the younger Pliny, who flourished in the first century of our era devotes some attention to the subject and makes a number of well founded observations regarding the incidence of a certain plantdisease. The Romans, like the Greeks, attributed the diseases of their crops to the

influences of the stars or other heavenly bodies and created special gods, such as the God Rubigo to whom they offered up prayers for protection.

It was not until some years after the invention of the microscope that their real nature was understood. The epoch-making discovery of Pasteur of the true nature of the process of fermentation and the development of the germ theory of disease mark the true starting point for modern pathological studies both for animals and plants. The first proof that a specific plant disease is due to the invasion of the tissues of the plant by a definite parasitic organism was furnished by the German scientist DeBary (1853) who is thus properly regarded as the founder of the modern science of plant pathology, at least in its theoretical aspects. DeBary's pioneer researches prepared the way for a host of other workers, at first chiefly in Germany and later in all civilized countries. The twentieth century has witnessed an extraordinary activity in the study of problems of plant diseases most strikingly perhaps in the United States of America. The economic importance of the subject as a branch of scientific agriculture is being increasingly recognised and the prosecution of researches in plant diseases is being more actively pursued by agricultural departments of all countries whose agriculture can claim to be progressive.

Chapter II

DEFINITION AND SYMPTOMS OF DISEASE

Disease in plants may be defined as variation from the normal as expressed either by the checking or by the interruption of physiological activities or by structural changes, which are sufficiently permanent to check development, cause abnormal formations or lead to premature death of a part of the plant or of the entire individual or failure of the plant to produce a commercial product of satisfactory quality and quantity. In health a plant is in what might be described as a condition of equilibrium, that is to say, all its internal functions and processes are graded to suit a particular set of external conditions. Its roots take up the right amount of water to keep the tissues well supplied, and this water contains the right amount of mineral food dissolved in it; its leaves manufacture, with the aid of the sun, enough starch to supply its requirements and so on.

Any thing that causes a plant to depart permanently or seriously from this condition of equilibrium produces disease.

Symptoms of Disease :

The study of the symptoms is the first step in the examination of disease. By symptoms one means the total of the modifications shown in the plant as the result of disease. In the majority of plant diseases of

Fig. 1. Brown spots on cabbage caused by *Alternaria Brassicae* (After Butler)

Fig. 2. Shot-hole of peach leaf (After Butler)

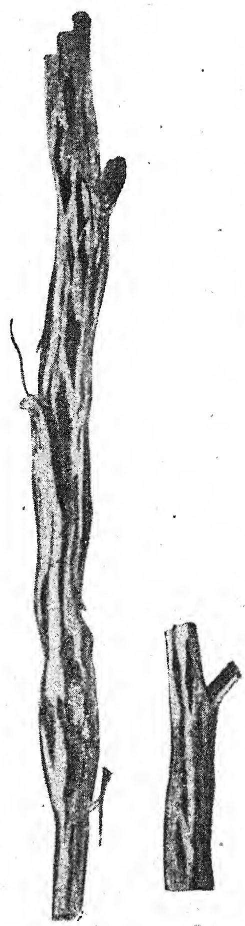

Fig. 3. Canker of Tea stem (After Butler)

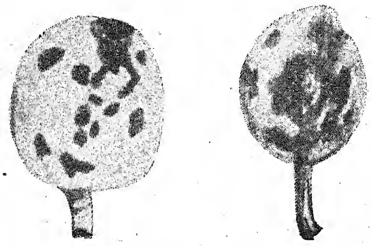

Fig. 4. Scab of apples (After Salmon)

Fig. 5. Prolification of spikelets of *Pennisetum*. (After Butler)

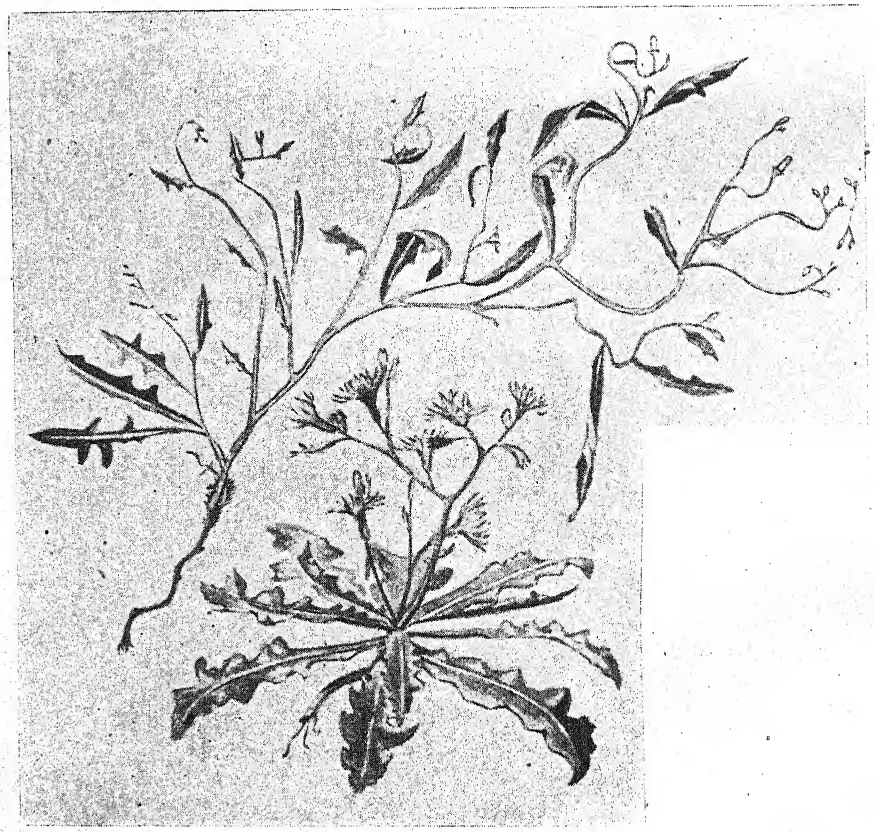

Fig. 6. *Launea asplenifolia*, normal plant below; plant attacked by *Puccinia butleri* above. (After Butler)

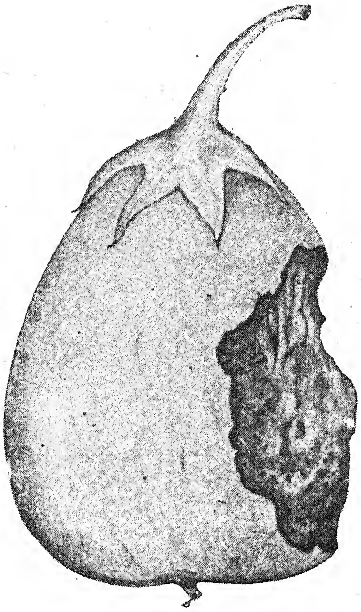

FIG. 7. Rot of Brinjal

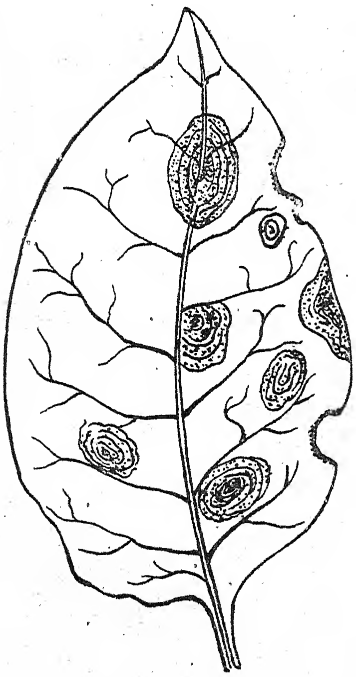

FIG. 8. Leaf spot of Potato due to *A. solani* (After Heald)

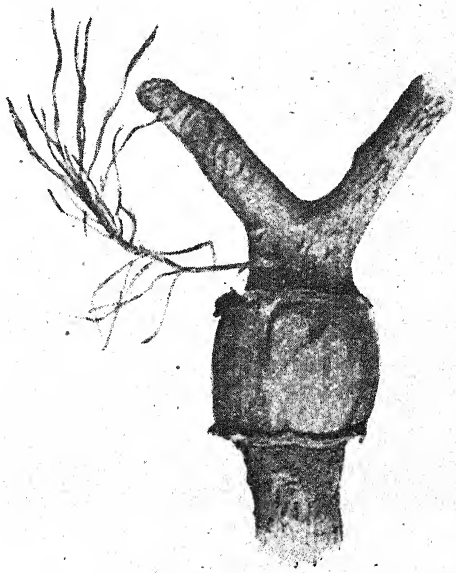

FIG. 9. *Peridermium* galls (After Heald)

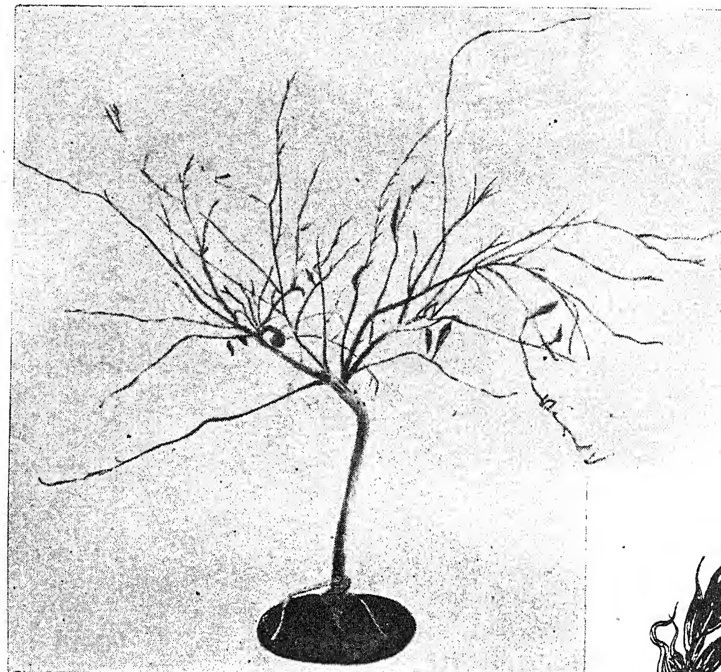

FIG. 10. Withering of orange (After Butler).

G. 11. Downy mildew of jra, ear changed partly to leafy structure (After Butler).

FIG. 12. Wheat smut, grains destroyed. (After Butler).

parasitic type the true symptoms are accompanied at one stage or other of the disease by certain appearances such as the fructification of the parasite. The latter are not symptoms in the strict sense of the term as they are not part of the host plant, but they are often loosely referred to as such. In some text-books of plant pathology they are spoken of as 'signs' of disease. It may be noted that signs of disease in the sense just defined are usually absent in the case of animal diseases of parasitic nature.

A more important difference between the typical plant disease and the typical animal disease is as regards the definiteness of the symptoms. In animals and especially in man disease symptoms are usually of a very characteristic nature, so that it is often possible to identify (or diagnose) a particular disease from a study of the symptoms alone. With plants this is not generally possible Disease symptoms in the latter are of a much more generalised nature or in other words the same or approximately the same set of symptoms can be produced by a great variety of causes. Wilting of the foliage, for example, is a symptom of a disease in plants and its cause may be most varied : damage to the roots by fungal or insect attack, damage to the stem, presence of injurious salts in the soil, scarcity of water, and so on. While thus the symptoms of plant disease are of a generalised nature, a number of different types may be distinguished. The more important of them are as follows :

(1) *Change of Colour* : This deviation from the normal may be noted on various plant structures, on the roots, stems and fruits, but the discolourations are very frequent and striking on parts which are normally green, such as herbaceous stems and foliage leaves. Plants, like people, frequently look pale when they are sick. Nutritional disturbances such as lack of iron, excess of lime, excess of alkali, presence of virus, fungal or bacterial parasite, lack of light or low temperature may prevent the production of chlorophyll and cause normal green structures to become pale green, yellowish green, white, red or silvery.

(2) *Leaf-spotting* : Discolourations, instead of being general or diffuse may show as more or less definite or circumscribed discoloured spots or areas. They form one of the commonest symptoms of disease These spots are very varied in colour, according to the plant and parasite concerned, and also often change colour at different stages in their development. In some cases the colour is not uniform, but zones or bands of different shades may alternate.

Pallid spots are common in the mildews and in the early stages of many other parasitic attacks.

Yellow spots are caused by rusts and some other fungi. Very often the colour changes to brown or black at a later stage. They are often rasied and covered when mature with a yellow dust composed of spores which may be rubbed off on the finger.

Red spots are found in some rusts and leaf parasites of cereals and sugarcane. In the leaf form of red rust of tea and other plants the spots are raised and often turn a sickly white when old.

Brown is the characteristic colour of dead tissues and is the final colour of the great majority of the leaf-spots, although some finally become greyish with age.

Black spots are almost always an indication of fungus attack. They are found in late stages of rusts and in many *Ascomycetes, e.g., Phyllachora, Rhytisma, Diplocarpon.*

Concentric bands of colour are found, in different shades of brown in spots caused by *Alternaria* and in brown, red and yellow in *Cercospora.*

(3) *Shot-Hole* : This name is given to the perforations in the leaves. At first a brown spot appears, but the diseased tissues are soon cut off from the rest of the leaf and ultimately fall off leaving a round hole in the leaf. They are common in fruit trees, such as peach and plum, and are found in tea and some other plants, but rarely in field crops.

(4) *Damping off :* This name is applied to the sudden collapse of seedlings, which are attacked at the base of the stem and fall over from weakening of the tissues at this point. It results from the rot caused by several fungi, *e.g., Pythium, Phytophthora, Rhizoctonia.*

(5) *Wilting* : The term wilting is applied to those cases where a whole plant dries up more or less suddenly from an attack at the root or base of the stem. It may be caused by fungi, bacteria, drought or frost. Some insects may cause similar symptoms. Drying up of a single branch is also observed in some cases; this is usually due to the infection of the branch by one of the canker or anthracnose fungi.

(6) *Death of parts or Necrosis :* In some diseases death of special parts or organs of the plant, as leaves, stems or twigs, buds, flowers or fruits is the first symptom of disease. The affected structures generally assume the characteristic dark or brown colouration of dead tissue and the accompanying disease is frequently characterised as a blight. Necrosis may be localised in certain organs, or it may be general and result in the death of the entire plant.

(7) *Scab :* This is a condition caused by cracking of the outer layer of fruits or tubers, the broken skin becoming dry, flaky, indurate or sometimes corky. The scabs of potato, apples and peaches are caused by fungi; citrus scab which is prevalent in this province and in other parts of India is usually due to bacteria. Eelworms may also cause scabbing of tubers.

(8) *Canker :* Open wounds often of a spreading nature and sometimes surrounded by a raised, tumour-like margin, are found on woody stems and even sometimes on annuals like pigeon pea. They are caused

usually by parasites that attack the bark and extend as far as the cambium. The raised margins are the results of efforts at repair by the production of callus, which may again be attacked and destroyed before healing has progressed far. Most canker producing fungi are *Ascomycetes* (Nectria) but some are rusts (*Peridium*) and *Hymenomycetes* (*Corticium*). Cankers are also caused by insects, frost and bacteria.

(9) *Dwarfing or Atrophy*: Either the entire plant or special organs may be reduced in size as a result of unfavourable factors either environmental or parasitic. The whole plant may remain stunted from early attacks of mildews, rusts and other fungi. The leaves may be atrophied as a result of the actions of some rusts and species of *Synchytrium*; flowers in poppy attacked by *Peronospora parasitica*, grasses with *Epicloe* and some cereals with *Sclerospora*; fruit in rusted cereals, and from smuts that infest the ovary. All these changes can also be caused by insect attack and several of them by unfavourable climatic conditions, poor soil and the like.

(10) *Increase in size or Hypertrophy*: Abnormal outgrowths of the most varied character are often found on the herbaceous parts of plants and also sometimes on woody stems and on roots and tubers. They may vary from tiny warts, involving only one or a few cells, to the rounded tumours, several inches across, of maize smut. Hypertrophied roots are well illustrated in the club-root or finger-and-toe disease of the cabbage and other crucifers; hypertrophied leaves in the well known leaf curl of peach; hypertrophied flowers or flower parts as in the white rust of the crucifers and hypertrophied fruits as illustrated by plum pockets or bladder plums.

(11) *Transformation of Organs:* This is found chiefly in flowers and results in the change of one kind of floral leaf into another or into ordinary leaves. The stamens may become leafy in bajra affected by *Sclerospora*. Petals may become like sepals, stamens like carpels and carpels leaf-like in the white rust of crucifers.

(12) *Alterations in Symmetry and Habit*: Some plants which under normal conditions are more or less prostrate or creeping become ascending or even erect when attacked by a fungus parasite. The short unbranched stem with radical leaves of *Launea asplenifolia* becomes an elongated, much branched axis with cauline leaves, when infected with *Puccinia Butleri*. Leaves may be changed from simple to irregularly lobed. Single flowers may be altered from regular (actinomorphic) to the irregular (zygomorphic) symmetry and *vice versa.*

(13) *Dropping of leaves, blossoms, fruits and twigs*: The leaves are shed as a result of the action of leaf parasites (*Cercospora personata*); they may also be shed after frost or in drought. The shedding of blossoms may be illustrated in the blossom drop of the

tomato and grape ; dropping of fruits by the shedding of bolls in cotton, coconuts due to the attacks of *Phytophthora*.

(14) *Rotting* : Succulent or woody stems and roots, fleshy leaves, flower buds or fruits may be affected with either dry or soft rot. The character of the rot may depend on the structures involved, the causal factors or complications and external factors. Rotting is often caused by *Phytophthora* and *Pythium* where the green parts are chiefly affected, by such fungi such as *Rosellinia* where the roots are concerned ; by *Rhizoctonia* where the region affected is usually the 'collar'. Many wet rots are due to secondary saprophytic organisms, chiefly bacteria, which follow in the track of the parasite.

(15) *Fluxes* : Several tree diseases are characterised by an exudation from the bark of the stem. The nature of the exudation varies in different cases. In the stem bleeding disease of the coconut a colourless or brown, somewhat viscid liquid, rich in sugars and product of decay of the tissues, oozes out from cracks in the stem. In rubber canker, there is an exudation of *latex* in the older stages. *Resin* is poured out in conifers attacked by various fungi. *Gum* is found on the surface of the diseased parts in the foot-rot of citrus trees.

(16) *Mummification* :—The transformation of fruits into shrivelled structures called 'mummies' is a phase of numerous diseases. The formation of mummies is a very characteristic feature of the brown rot of stone or pome fruits. Other typical illustrations may be found in the bitter rot and black rot of apple and grape. 'Mummies' are dried up shrivelled fruits containing the mycelium and sometimes the spores of the parasite; they remain hanging in the tree or fall on the ground.

(17) *Development of dormant rudimentary or new organs* : New shoots are formed from the base of the rice plant attacked by *Sclerotium Oryzae*. The rudimentary stamens in pistillate flowers of *Lychnis dioica* become fully developed when attacked by *Ustilago violacae*, except that the pollen is replaced by the spores of the fungus.

(18) *Malformations* : The following abnormal formations may be included under this heading : *Intumescences* or pustule-like distentions of tissue, occurring most abundantly on leaves but also on stems or fruits, due to the abnormal elongation of groups of cells.

Galls or localised enlargements on various organs in the form of small pustules or warts, larger tubercles, tumours or masses of cells making a morbid outgrowth of either fleshy or woody character, in which host tissues and parasite mingle.

Rosettes or closely grouped clusters of leaves caused by the failure of axes to make a normal elongation. This should not be confused with the normal rosette habit of certain plants.

(19) *Witches'-brooms*: This is a condition of closely grouped clusters of fine slender branches, generally arranged more or less parallel to each other, and frequently originating from an enlarged axis.

(20) *Prolification*: By this is meant the continued development of a part after it has reached the stage at which it normally ceases to grow. It occurs in the ears of bajra and *Setaria* attacked *by Sclerospora graminicola*, the central axis of the flower growing on into a stunted leafy shoot, surrounded at the base by the glumes and stamens.

Chapter III

CAUSES OF PLANT DISEASES

The diseases of plants are either due to the attacks of parasites or due to non-parasitic influences. The different causes of the plant diseases may be grouped conveniently as follows:

I. *Parasitic Diseases*: These are caused by (a) plant parasites such as fungi, bacteria, flowering plants; and (b) animal parasites, such as insects and microscopic animals (*e g.* eelworms or nematodes). The study of the diseases caused by eelworms comes under the purview of the science of *Phytopathology*. But the study of insects requires a separate field of investigation, *Entomology*.

II. *Non-parasitic Diseases*: They include a great variety of nutritional disturbances due to lack of proper inherent qualities, to improper conditions of soil or air, or to injurious mechanical influences.

III. *Virus Diseases*: Include a group of diseases in which the disturbed condition is the result of an infectious principle, a so-called *virus* which can be transmitted from diseased to healthy plants and can communicate the disease.

I. PARASITIC DISEASES

(a) Fungi

The most widely distributed and most destructive of plant diseases are caused by organisms known as fungi. These are small plants devoid of green colour, found on large green plants. They produce spores which take the place of the seeds in higher plants. The spores germinate and produce one or more filaments known as germ tubes These grow in length branching in all directions and the resulting branched mass of threads or filaments often have a cobwebby appearance. These threads or filaments are collectively known as *mycelium* which constitutes the vegetative part of the fungus. This vegetative part is concerned with the growth and the absorption of food or its manufacture into living substance as distinguished from the reproductive part (spores) concerned with the propagation of the species. Each individual thread of the mycelium is called a *hypha*.

Mycelium : At an early period in its growth, the germ-tubes and the hyphae which arise from it usually become segmented into a row of cells by the formation of transverse walls (septa) across the filament. Each cell is a hollow structure, bounded by walls of a pliable, transparent substance, which is in some cases composed of the chemical compound cellulose. Within the walls the cell is filled with *protoplasm* ; the protoplasm does not fill the cell all through with a uniform mass. Here and there little hollows and spaces called 'vacuoles', occur containing water with dissolved substances, the whole forming the cell sap. Here and there also condensations of a peculiar form of protoplasm form what are known as *nuclei*. In segmented filaments, each cell usually contains one *nucleus* only. In some cases two, three or more nuclei have been found in each cell. In the lower fungi, the mycelium is ordinarily unsegmented, no transverse septa being formed. In such cases the nuclei are distributed irregularly in the protoplasm.

Sporophores : As the mycelium is usually buried in the substance on which the fungus feeds, in the soil, in rotting organic matter or in living plants and as it is necessary that the spores should be formed in free access to the air so as to secure their dissemination, it is evident that some special arrangement must be made to bring the spore-forming parts where they will be exposed to the elements. This is done usually by the development of structures known as *sporophores* raised vertically above the level of the general mycelium. The sporophore may consist of a single hypha (simple sporophore) or of bundles or complex masses of hyphae (compound sporophore), and it bears on some part, usually towards the top, the spores of the fungus. The hyphae of which it is composed ordinarily differ from those of the vegetative mycelium in one or more characters, such as their vertical position, limited growth, or special structure (nature of the cell wall, shape of the cells, characteristic mode of branching and the like), and as they may be arranged in systems of great complexity, an almost endless series of different types of sporophores exist.

Reproduction in Fungi :

The reproduction in fungi, that is to say, the production of a new generation from the old is secured by the cutting off of specialised cells from the fertile hyphae which develop into *spores*. When ripe these spores separate from the mother plant and are capable on germination of giving rise to new individual. In certain cases the spore is formed after the contents of two separate cells fuse wholly or in part. This is termed *sexual* reproduction. In very many cases, however, the spores are formed asexually, without any preceding fusion of two cells.

Sexual Reproduction : Sexual reproduction among fungi involves the union of the contents of two uninucleate or multinucleate gametangia which may be similar in structure and behaviour or may be

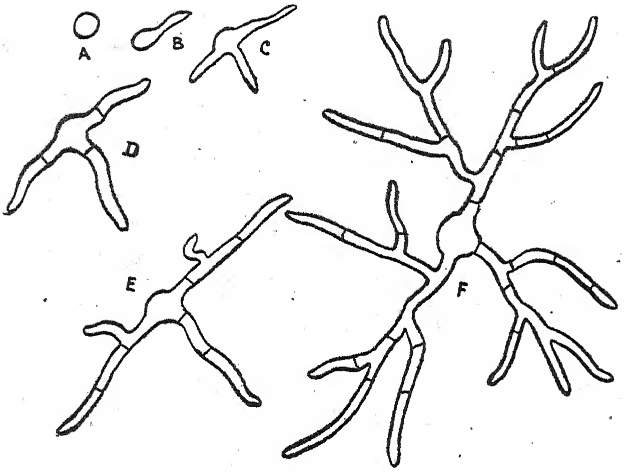

FIG. 13. Outline diagram of a spore of *Penicillium* and stages in its germinatio to form hyphae and a young septate mycelium (After Heald).

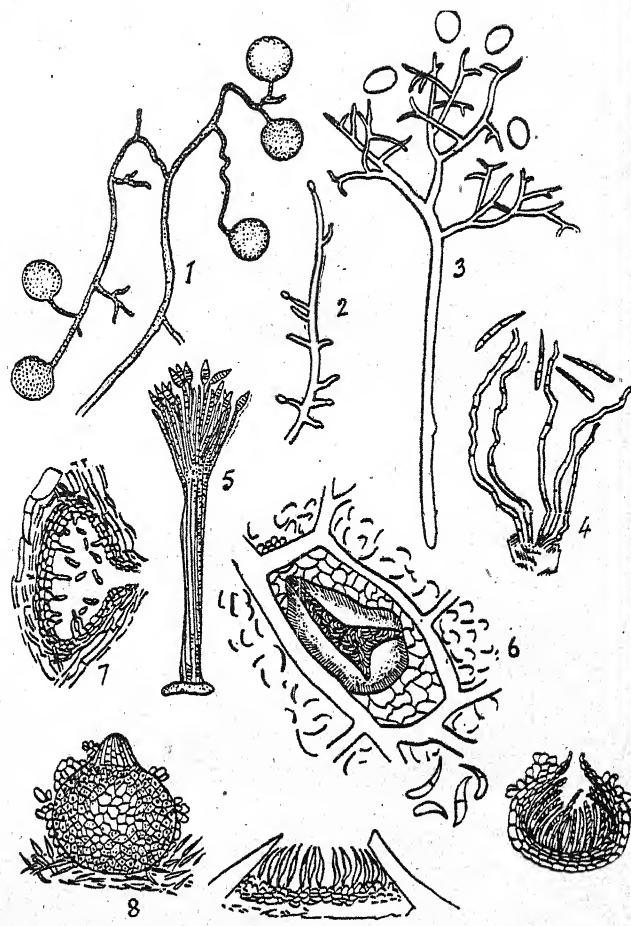

FIG. 14. Sporophores: 1. *Pythium de Baryanum*; 2. *Cephalosporium Sacchari*; 3. *Peronopora Viciae*; 4. *Cercospora longipes*; 5. *Arthrobotryum* sp. 6. *Marssonia juglandis*; 7. *Ascochyta Pisi*; 8. *Nectria Bolbophylli* (After Butler).

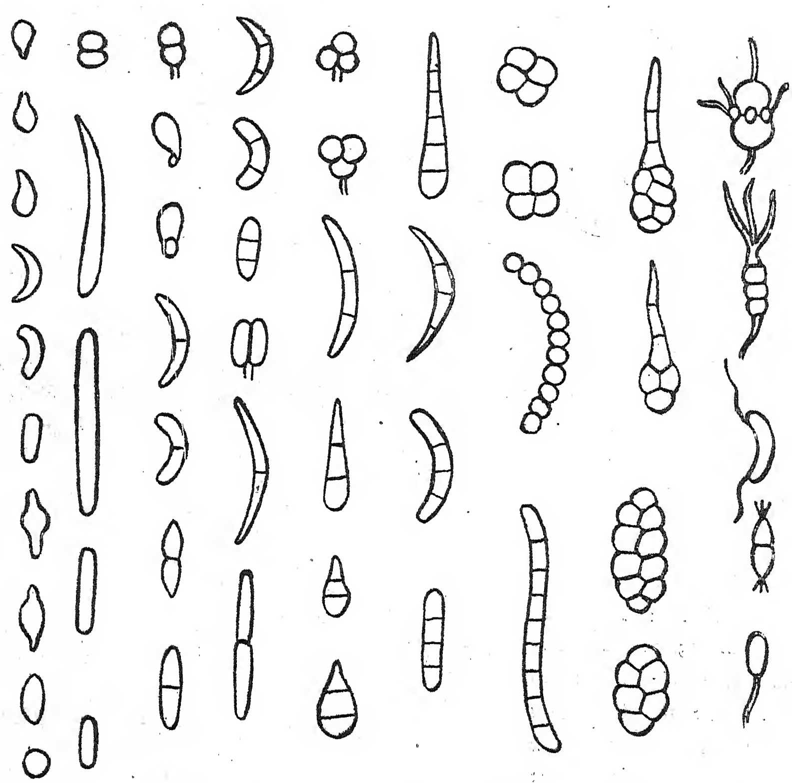

FIG. 15. Diagrams of various forms of Spores.
(After Heald)

differentiated as an *antheridium* and *oogonium.* Each of these organs may produce one or more distinct gametes or the contents may remain continuous and the gametes be indicated by nuclei lying in an undifferentiated mass of cytoplasm.

The replacement of normal sexual fusion by the union of two female or two vegetative nuclei, or of a female and a vegetative nucleus, is common among fungi, and the complete disappearance of even this reminiscence of a sexual process is still more frequent. Almost every group of fungi shows a progressive disappearance of normal sexuality.

In the higher fungi the sexual spores are produced either endogenously, as *ascospores* in a mother cell of limited size termed an *ascus* or exogenously as *basidiospores*, on the exterior of a cell or row of cells known as a *basidium.*

Asexual Reproduction : The asexual or accessory methods of multiplication have no relation to sexual process. In many of the lower fungi, *zoospores* are developed in spherical or tubular *zoosporangia* ; this is especially common in aquatic form. In connection with the change from aquatic to subaerial conditions, the contents of the sporangium may come to be shed as walled non-motile spores, or the sporangium itself may be set free without division of its contents. Such a structure borne externally on its parent hypha, is termed a *conidium* and is the characteristic unit of accessory multiplication among fungi. In the great majority of cases the conidium germinates by means of a germ-tube but where the fungus has not completely abandoned an amphibious habit the conidium, if it falls in a wet situation, may give rise to zoospores. Conidia are commonly developed either singly or in groups, upon stalks known as *conidiophores* ; these may be free ; they may be gathered into a sheaf or *coremium* ; they may constitute a *hemispherical* cushion termed a *sporodochium* or they may be produced within a special, flaskshaped receptacle, the *pycnidium.* They show almost an endless variety of forms and arrangement.

A less common propagative cell is the *clamydospore*; these are formed either singly or in chains in the course of the ordinary vegetative hyphae or on special branches. It is not unusual for vegetative hyphae to divide into short segments which break apart, are disseminated and give rise to new plant. To these structures the term *oidium* is applied.

Many conidia and other thin-walled spores possess the power of *budding*, giving rise, that is to say, to lateral outgrowths which are soon nipped off as new cells.

Morphology and Formation of Spores :

The spores of fungi present a wonderful range of variation, there being hundreds of types differing in size, shape, structure and mode of

formation. The one fungus may have several different kinds of spores during the course of its life-history.

The individual spore whether it belongs to the principal or accessory fructification, is, when first formed, a single hyaline that is transparent colourless cell; in the course of development it may divide and become a mass or row of cells; either its wall or its contents may become coloured and its cytoplasm often develops large oil globules. The spore is usually enclosed in a double wall consisting of a delicate *endospore* and an *epispore* which may be smooth or sculptured. The spore may be borne on a specialised outgrowth the *sterigma*.

According to their mode of development two main types may be distinguished :

(i) The spores are formed by the dividing up of the inner contents of a mother cell into a number of cells, which become separated from one another, as a rule, while still enclosed within the mother cell, and are ultimately set free by the rupture of the wall of the latter. This is called *endogenous* spore for mation.

(ii) The spores appear as protrusions of the tip or at the side of the fertile hypha, and are cut off, when they reach maturity, by a septum which usually breaks through and sets them free when ripe. This is called *exogenous* spore formation.

Types of spores :

According to the manner in which they are formed, to structure or to other peculiarities, different names are applied to different types of spores. The swimming spores of aquatic fungi and their allies are termed *zoospores.* The spores formed within the asci are known as *ascospores.* Those of the *Basidiomycetes*, *basidiospores* or *sporidia*.

In species where besides a formation of spores in sporangia, asci, or on basidia, a second type of spore production exogenously occurs, this second form of spore is usually termed a *conidium.* Conidia formed in enclosed receptacles (*pycnidia*) are often called *pycnospores.* In such fungi as the rusts where a number of spore forms are known in one and the same individual, special names may be applied to each. Thus a perfect rust fungus may possess *spermatia*, *aecidiospores*, *uredospores*, *teleutospores* and *sporidia*, all differing in shape, structure and mode of formation and most with different properties and uses.

Spore Resistance :

The presence of moisture is often a crucial factor in determining the life of a spore. The spores of many of the aquatic fungi cannot endure a dry atmosphere for any considerable length of time. When such spores are dried they lose their power of germination, they are

dead. The great majority of fungus spores can, however, endure desiccation with perfect impunity. Such spores as smut spores have been known to retain their vitality for eight years or more in an air-dried condition. The spores of the ordinary green moulds are also capable of living in dry atmospheres for a very long time.

Moreover, the air-dried spores of fungi are in general capable of resisting high and low temperatures, much more so than spores in moist conditions.

Dissemination of Fungi :

A fungus may be disseminated by the mycelium or by spores. The former can usually only be carried with the substance on which it is growing and sufficiently large pieces to contain portions of mycelium that will survive are not often carried far except by the agency of man. Several parasites have, however, been widely distributed in the mycelial condition with the plant on which they grow, as for instance, the well-known potato blight.

The great majority of fungi are ordinarily disseminated by spores. As these are very minute bodies (usually invisible to the naked eye) and are so light as to be easily taken up into the air as impalpable dust, the wind is the chief agent in securing dissemination ; there are, however, many subsidiary methods of spread. For dissemination by the wind many fungi are peculiarly well-suited. They often produce spores in enormous quantities up to seven million million having been calculated to be contained in the sporophore of *Lycoperdon bovista*, one of the puff-balls. When closed in receptacles there are sometimes arrangements for expelling the spores forcibly in the air. Many spores have tiny spines on the wall or are sticky on the surface ; this helps to anchor them to leaves or other suitable places for germination. Others have thread-like tails which doubtless assist both in keeping them in the air and in fastening them to their support when they fall.

Water may serve also for the dissemination of fungal parasites. Actively motile cells are produced by water moulds, the chytrids, the white rusts and some of the downy mildews. Such forms depend wholly or in part upon liquid moisture as a medium in which they may develop and through which they may migrate by the action of their flagella or cilia. Flood water, irrigation water or stream flow may be responsible for the spread of many pathogenic forms. Dissemination by stream flow is well illustrated by the forms of ergot affecting aquatic grasses in which the sclerotia are 'floaters' and so are carried down stream to new hosts.

The dripping of moisture from heavy dews or the run off from rains may transport non-motile spores ; those which have been lodged on plant parts by wind or other agencies and are held together by a mucilaginous matrix in which they are embedded.

Insect may act simply as carriers of infective material adhering to their bodies and in certain cases make the inoculation by feeding wounds, either by chewing or sucking mouth parts. The other forms of animal life credited with the dissemination of diseases are nematodes, slugs or snails, birds and wild or domestic animals.

Man is an important agent in fungi distribution. In all of his commercial transactions, such as shipments of grains, introduction of plants and moving of commodities, fungi of many kinds may be introduced and spread over vast areas.

True seed and also vegetative reproductive structures such as tubers, corms, rhizomes, cuttings, grafts may carry the pathogene (mycelium and spores) on or within their bodies or as separate bodies mingled with the seed.

By the transport of soil, litter, compost or manure fungi may be introduced into new environments. They may also be spread by the ordinary operations of transplanting seedlings, by watering, by spraying, by picking or harvesting operations and by threshing and ginning.

The large group of soil-inhabiting fungi which do not often produce aerial sporophores are liable to be carried by irrigation water or by surface wash after heavy rain. Infected soil may also carry the spores and mycelium of such fungi and may reach other fields in various ways as on the boots or feet of farm workers and pedestrians, or on agricultural implements.

Conditions of Spore Germination :

When a spore is placed under proper conditions of moisture, temperature and of other factors, it germinates, *i. e.*, grows out into a fine thread which, if conditions remain favourable, develops directly into the fungus mycelium. By far the largest majority of fungus spores are capable of germination as soon as they are ripe, provided of course that such external conditions as light, moisture, etc , are favourable. Many so-called resting spores are forced to undergo a certain resting period after maturity before they can germinate. Such spores are provided with thick coats for protection.

Polymorphism :

One of the most curious circumstances in the life-history of fungi is their capacity for assuming different forms at different periods of their full development. To this the name '*polymorphism*' is given. The *Ascomycetes* and the rusts are particularly rich in polymorphic species. Polymorphisms, however, occur to some extent in all groups. One example may be cited here.

A species of rust known as *Uromyces Fabae* is common on peas, broad beans and lentils in our country. The first sign of its appearance is an outbreak of tiny, yellow dots in clusters on the stem and leaves. On examining these under the microscope they are found to be flask-shaped sporophores, sunk in the tissues and containing a large number of minute spores. This kind of spore receptacle of the rusts is called a '*spermagonium*' and the spores produced within '*spermatia*'. Very soon larger yellow eruptions the *aecidia* appear in the same part of the stem and leaves as the first and on the same mycelium. A little later, pale brown pustules, the *uredosori* appear scattered all over the plant. They consist of the *uredospores*. Still later, large blackish brown pustules are found, chiefly on the stem. These are the *teleutosori*, in structure similar to the last, but bearing the perfect type of spore, the *teleutospores*.

Fungus Life Methods :

The spore on germination gives rise to a germ-tube which at first is nourished by reserve food stored up in advance. Very soon the young hyphae begin to feed for themselves. As in the case of other plants the food must be dissolved before it can be taken in. This is necessary because solid particles cannot pass through the cell wall of the hyphae Liquid can, however, pass through, and the food dissolved in them reaches the interior of the hyphae by a process of osmosis. The great difference between the fungi and the green plants which possess chlorophyll is that the former cannot build up their essential carbonaceous food out of the carbon dioxide of the air. They require their food, therefore, ready prepared.

According to the manner in which fungi obtain their organic food they are divided into two great classes: *Saprophytes* and *Parasites*.

Saprophytes obtain their organic food from the dead tissues of animals or plants, or of substances derived from them. Hence they are found in large numbers in the soil, pervading every bit of rotting leaf or twig or particle of manure. They grow as moulds on fruit and jam and on boots and the backs of books in the rains. Every bit of old timber in the forest is liable to be permeated all through with their hyphae.

Parasites obtain their food from the living tissues of animals and plants. Thus the parasites are almost entirely hurtful. The great majority of parasitic fungi feed on living plants useful to man. The few cases of beneficial parasites from the point of view of man, are those which attack noxious insects and occasionally destroy large numbers of them.

Several different classes of parasites may be distinguished. *True* or *obligate parasites*, for instance, pass through the whole of their life cycle on living plants and cannot be grown on dead or artificial

food material and the death of the host involves the death of the fungus. *Hemi-parasites* are those that feed usually on living tissues but can, at need, pass through a part of their lives as saprophytes. *Hemi-saprophytes* on the other hand, are those which usually grow on dead or decaying matter and are capable of passing through the whole of their development as saprophytes, but have at the same time the faculty of attacking living tissues under certain conditions.

The Mode of Life of Parasitic Fungi :

In general, there are two methods of life. The fungus may live on the surface or it may live within the tissues of the host plant. Those which live on the surface are known as '*ectoparasites*' and those which live within '*endoparasites*'!

Ectoparasites include those forms which grow on the surface of the leaves, stems or other parts of the affected plant, and obtain their food through the outer cell walls without penetrating deeply into the tissues. They feed usually by means of special outgrowths from the hyphae, known as suckers or *haustoria*. These arise from hyphae in contact with the epidermis and penetrate wholly or partly through the toughened outer walls of the epidermal cells. All the body of the fungus lies outside the plant, excepting these haustoria, and there are even several cases where haustoria have not been detected and it seems as if the food is absorbed directly from the outer cell across the unbroken cell wall.

Endoparasites, on the other hand, penetrate into the plant and develop their vegetative mycelium within the tissues. Sometimes the internal mycelium is confined to a small part of the plant as in the case of the numerous leaf-spotting fungi, where each little patch of invaded leaf-tissue shows a discoloured spot owing to death of the cells. When a single spore of one of these leaf-spotting fungi germinates on a suitable leaf, the germ-tube penetrates into the leaf, grows, branches and the resulting hyphae spread all around in the tissues. Their food is obtained from the cell sap of the living leaf cells, either by the hyphae or suckers from them growing directly into the cells in search of it, or by absorption through the walls in the case of such fungi as live between not inside the attacked cells and which have no haustoria. When a certain amount of food has been obtained and a certain number of leaf cells killed, the fungus ceases its vegetative growth and reaches the reproductive stage. In other endoparasites, the growth may extend to considerable part of the plant and reproduction may occur while vegetative growth is still going on. The formation of spores within the tissue would be of little use in disseminating the fungus, so the endoparasites practically all send out special sporophores to the surface of the plant, and form their spores in the outside air. In some cases a second kind of spore,

usually a sexually formed resting spore, is developed within the tissues and this is only set free and germinate when they have rotted. The use of this second spore form is generally to carry the fungus over some unfavourable season so that germination will only occur when conditions are again suitable for general life of the fungus.

Methods of Host Penetration :

When the spore of a parasitic fungus falls on the leaf of a host it awaits favourable conditions for further development. When the moisture, temperature and other conditions are most favourable, the spore sends out the germ-tube which in many grows directly to a ventilating pore of the leaf and enters the plant through the stoma or by direct passage through the outer wall of the epidermis. In woody or corky parts, penetration may occur through the air passage of the lenticel, through cracks in the bark, or directly through the cell walls. Most of the stem parasites of trees enter through wounds especially those due to the breaking of branches or the action of insects. In some cases stem parasites can enter through dead branches.

Infection of roots may be by direct boring through the uninjured epidermal or cortical cells or through wounds or cracks in the bark. Usually the first type occurs in young root the second in the old ones.

Many parasites can only enter through definite parts of the host plant, though the subsequent growth may be diffused, and spore production may occur at a distance from the point of entry. In oat smut for instance infection occurs through the mesocotyl of the germinating seed, but the spores are formed some months later in the ears In the loose smuts of wheat and barley and in some *Sclerotinia* infection occurs through the stigma of the flower; in ergot through the young ovary.

Preparation of the Food for Absorption :

Having arrived in contact with the food, the work of the parasites is not, however, finished. Very often the cell substances are present in an unsuitable form and must be altered to enable them to serve as nutrition for the fungus. Starch for instance which is present in so many vegetable cells, has to be changed to sugar and cane sugar has sometimes to be converted to glucose. Living protoplasm has to be killed and altered into other nitrogenous compounds such as peptone ; glucosides have to be split up to liberate carbohydrates, such as glucose which may serve as food ; fats are also probably split into glycerine and fatty acids. In those fungi which make use of the cell membranes, cellulose and pectic bodies have to be dissolved. These processes are carried out by means of ferments in which fungi, both parasitic and saprophytic are exceedingly rich.

Life History of Parasitic Fungi :

A parasite of the roots or stems of perennial plants or the leaves of evergreens has always available the food supplies requisite for its development. It may be and often is, dependent on seasonal variations of activity, but is rarely put to such traits to tide over periods unfavourable to its existence as the forms which live on annuals or the leaves of deciduous plants. Most of the common crop pests, many and many others forms have to face a period of the year when their ordinary supports are not available. The different methods adopted by fungi to solve this problem are of considerable interest though they are not in all cases by any means completely understood.

In the plains of India, for instance, the wheat season is roughly from November to April and it is exceedingly rare to find even a self-sown wheat plant between May and October. The fungi which are parasitic on wheat have, therefore, to pass through a period of about half the year in some other way than as active wheat parasites.

As regards the mildew disease of wheat the *perithecia* of the fungus live in the soil or stubble. In the cold weather the mature ascospores are set free by the rupture of the perithecium which reach the growing wheat plants no doubt usually with dust and infect the crop.

In bunt the spores remain adherent to the wheat seed grain, which they reach during harvest, threshing or storing, and are sown with the crop for the following season. Both parasite and host germinate together and infection takes place in the seedling stage. Under certain conditions the bunt fungus can also live as a saprophyte in the soil, budding off sporidia in large numbers. If this saprophytic life be prolonged and the new wheat be sown in the same field or manured with contaminated manure, infection may occur. Many other hemi-parasites owe their persistence largely to their power of passing a more or less prolonged period as saprophytes in the soil or plant debris, until a new food crop is available.

The loose smut of wheat, on the other hand, persists from one season to the next in the mycelial condition in the seed. The mycelium remains in the grain in a dormant condition until it is sown, when it resumes activity and passes up into the seedlings, keeping pace with the growth of the latter until it is able to form new spores in the young ears. Other similar cases are known in several of the plant diseases such as the bean anthracnose, the gram blight, the potato blight.

Another type of persistence in the mycelial condition is found in many fungi which form *sclerotia* and other mycelial condensations. *Sclerotium oryzae*, for instance, lives between successive crops of rice chiefly as sclerotia in the soil.

In many cases the parasite is capable of living in more than one host plant, sometimes on a large number belonging to several different natural orders. This naturally helps to keep it alive when suitable food plants are found throughout the year.

Finally, there are cases in which we do not know yet clearly how persistence of the parasite is effected.

Heteroecism :

The great majority of parasitic fungi pass through their life history in or on the tissues of a single host plant ; such forms are said to be *autoecious* in contradistinction to the *heteroecious* forms which require two alternating hosts for the completion of their development. With the exception of the ascomyctes species *Sclerotinia Ledi* all known heteroecious fungi belong to the rusts.

Specialisation of Parasitism :

Fungi vary in the extent to which they are adopted or restricted to a particular habitat ; in some species the range is wide, in others the range is narrowed. Many fungi are again limited, either as parasites or saprophytes, to the members of a particular family, a particular genus, even a particular species.

Amongst those fungi which are capable of attacking several different species of plants, many have developed into distinct races each of which though outwardly similar to the others, is restricted to one, or a few only, of the host plants. A single species of fungus such as *Puccinia graminis* may include a number of these races, all quite similar in structure and not to be distinguished from one another in any other way than by their capacity for living on certain hosts. The difference between them is physiological not botanical. The name 'physiological' or 'biological' species or forms has been given to these races. To this splitting of a parasite into specialised races on different hosts plants, the term *specialisation of parasitism* is applied.

Classification of Fungi :

The fungi as a whole are divided into three main classes according to the septation of their mycelium and the character of their principal spores: *Phycomycetes*, *Ascomycetes* and *Basidiomycetes*. To these must be added as an appendix, the *Deuteromycetes* (*Fungi Imperfecti*) which multiply by conidia, and are probably, for the most part, incompletely known or degenerate members of the *Ascomycetes*, the mycelium and accessory fructifications of which they closely resemble.

The fungi are further subdivided into groups, alliances and families.

The *Phycomycetes* are known as alga-like fungi. They constitute the simplest forms of fungi and include the aquatic fungi and the simplest land fungi. Their hyphae never unite into strands or tissues, and the mycelium is either filamentous or composed of isolated, rounded cells. Regular septation is never found, so that the living parts of the hyphae usually form a continuous cell. The characteristic asexual fructification is the sporangium. Conidia are also found in some orders. Sexual reproduction is of a simple and distinct type. The receptacle bearing the female organ or egg (*oosphere*) is called the *oogonium* while the receptacle bearing the fertilizing or male organ (*sperm*) is known as the *antheridium*. The product of union of these two sexual organs or gametes is called *oospore*

Such serious diseases as bud rot of coconut, 'damping off' of seed lings, the downy mildew of jowar and maize and blight of potato are caused by fungi belonging to this group.

The *Ascomycetes* include a great number of forms, all agreeing in having spores developed within a mother cell, the *ascus* In most the asci are produced on, or in special sporophores; these are known as *perithecia* when round or flask-shaped and enclosing the asci in the hollow cavity and as *apothecia* when the asci are exposed. Conidia of the most diverse sorts are also usually borne.

A great many fungi belonging to this group are plant parasites. Amongst the numerous diseases caused by fungi of this group may be mentioned the false smut of rice and the powdery mildews of many crops.

The *Basidiomycetes* include a very large number of the higher fungi, representing the most diverse types. All, however, have the character that at some period in their life history, following the the completion of a sexual act, spores are formed on sterigmata produced from special fertile cells, the basidia. Each *basidium* produces on its distal end short stalks, called *sterigmata*, usually four, and on the end of each a spore known as either *basidiospore* or *sporidium* is borne.

To this group of fungi belong the mushrooms and the rusts and smuts that are serious diseases of some of our principal crops, such as wheat, barley, oats, rice, sugarcane, etc.

The *Deuteromycetes* comprise a large number of conidium-bearing fungi, some of which have been proved to be merely stages in the life-history of *Ascomycetes*, more rarely *Basidiomycetes*. The vast majority, however, appear to exist habitually as independent individuals having probably lost any other method of reproduction than that by conidia They are entirely devoid of sexual reproduction.

The *Fungi Imperfecti* includes both saprophytic and parasitic fungi. The latter cause diseased lesions on leaves, stems and fruits of plants

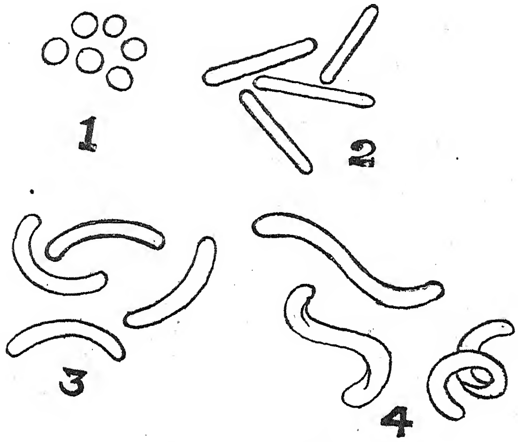

FIG. 16. Forms of Bacteria :
1. Coccus. 2. Bacillus. 3. Vibrio. 4. Spirillum.

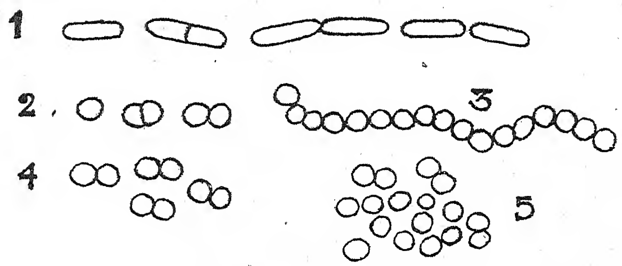

FIG. 17. Vegetative reproduction of Bacteria 1, Bacillus with successive divisions, 2, Coccus giving rise to chain 3, Pairs 4, Irregular groups 5.

(b) Bacteria

One does not usually associate bacteria with diseases in plants, but they are, nevertheless, frequently agents of such disease. In recent years many diseases of bacterial origin have been discovered and described. Man's chief interest in bacteria is usually centered in the diseases of man which are so largely caused by bacterial action. But in 1896 Smith stated that 'there are in all probability as many bacterial diseases of plants as of animals.' In 1920 the same author reported the occurrence of specific diseases on host scattered through more than 150 genera and over 60 families. Many of the hosts are important cultivated plants and wild plants of economic importance. Each year since the publication of the statement quoted has witnessed numerous additions to the long list of recognised bacterial diseases of plants.

The proof that the bacteria are the cause of plant disease (fire blight of the pear and apple) was first furnished by Thomas Burrill, professor of Botany in the University of Illinois (1879-1881).

Forms of Bacteria :

The body of a bacterium consists of a single cell into the minute structure of which it is not necessary to enter here. It is sufficient to note that there is a central body of protoplasm which stains readily with aniline dyes of various kinds, and a skin or *capsule*, usually so thin as to be practically invisible except by the aid of the highest powers of the microscope. The capsule or cell wall is not composed of cellulose as in the higher plants, but of a material apparently allied to the protein substances.

The whole body or cell is met with in many forms. Some kind of bacteria are spherical, each individual being then termed a coccus. When much longer than broad the bacterium is known as a bacillus; a comma-shaped form is spoken of sometimes as a vibrio ; a rigid spiral form in shape like a corkscrew is a spirillum.

Under certain circumstances bacterial cells may become distorted and irregular in shape. Such are known as involution forms

Size of Bacteria :

Bacteria are amongst the smallest of all living things. Their dimensions are usually stated in thousandths of a millimetre. One thousandth of a millimetre (·001 mm), known as a micron, is denoted by the sign $1/\mu$ and is equal to about 1/25000 of an inch. Cocci range from less than $\cdot 5/\mu$ up to $2/\mu$ in diameter ; bacilli from $\cdot 5/\mu$ or less in breadth to $10/\mu$ in length ; the majority, however, are much shorter than the latter figure. On account of their minute size they are, when

dry, readily blown about by the slightest breeze, and find their way into any crevices wherever dust can penetrate. They are carried in streams of water, and are to be found in and about all foods, milk and other liquids, in houses and stables and in the soil, on the skin and in the stomach and intestines of all animals. They are, however, never met with in the blood or tissues of healthy animals or plants and are rare in water which has come from deep wells or springs or has been filtered through great depths of soil and rocks.

Movement of Bacteria :

When bacteria are viewed under the microscope in a living condition many of them are seen to move. They can rove from one part of a drop of water to another as readily as fish in a pond. This is brought about by the lashing action of one or more exceedingly delicate hair-like *cilia* or *flagella* which are attached to the outer coat or capsule of the bacterium. Some organisms possess only one flagellum at one end (*monotrichic*), others two or more in a tuft at one or both ends (*lophotrichic*), while many bacilli have many flagella distributed all over the cell wall (*peritrichic*).

Reproduction in Bacteria :

Reproduction among the bacteria is largely asexual and takes place ordinarily by what is known as binary fission. In addition to this a number of bacteria go into a resting stage or produce spores. The spore formation is not, however, a method of multiplication because usually only a single spore is formed in a cell, but serves to tide the organism through unfavourable conditions.

(i) *Vegetative Reproduction*: When bacterial cells reach their adult normal form, if the conditions of temperature and nutrition are satisfactory, a partition or septum is developed across the cell which divides it into halves. The two halves or daughter cells, then grow to an adult size and undergo similar division. The process is repeated and vast numbers may arise in this way. A bacillus will divide into two bacilli in about twenty minutes; each of these new organisms will at once begin to grow, and in twenty minutes division will again take place. This means that under ideal conditions a single bacillus would in eight hours produce 16,000,000 descendants. The weight of a single organism is infinitesimal but in twenty four hours it would, if allowed complete growth, produce about 500 tons of bacilli.

It follows that if ideal conditions were available to bacteria the world would be swamped by their growth There are, however, many factors operating against this possibility. Only the common organisms grow at the rate mentioned, and many require days or even weeks to produce any appreciable weight of material.

(ii) *Spore Formation* : A considerable number of bacteria form spores within the cell. Because they are formed within the cell, they are spoken of as 'endospores'. Endospores are formed by the bacilli and the spirilla and their chief value to the cell is their ability to resist unfavourable conditions which to the ordinary vegetative form of the cell would prove disastrous The spore is formed by the contraction of the protoplasm within the cell. The protoplasm of the spore is denser than that of the original mother cell and the coat of the spore is a somewhat thick membrane. The number of spores which originate in each bacterium is generally one, though in one or two kinds two or more spores are seen in each cell.

When placed under favourable conditions of temperature, and provided with a suitable moist nutrient and a proper air supply the spore germinate by the rupture of the spore wall.

Food of Bacteria :

Like the fungi bacteria are also plants devoid of the green colouring matter called chlorophyll. Hence, they cannot manufacture their own food materials. In respect of the source from which the organic compounds are derived two classes of bacteria may be recognised, *viz.*, *saprophytes* which obtain their food from the dead and decaying bodies of plants and animals, or the lifeless organic matter in the soil, milk, water and of other common materials ; the *parasites* which feed upon materials present in the tissues of living organisms, plants and animals.

How Bacteria invade Plants :

The external surface of the plant body of seed plants is covered in large part by an epidermis with an external cuticle or also with cuticularised external walls or by a more impervious layer or cork cells, the periderm. Some parasitic fungi are able to make their way through such unbroken epidermal walls, but pathogenic bacteria seem unable to penetrate cuticularised walls or layers of cork cell. This leaves wounds or mechanical injuries of various kinds, stomata, water pores, nectaries and lenticels as the possible avenues of entrance.

Location of Bacteria in Diseased Tissue :

The majority of bacteria which cause disease in plants enter into the tissues of various organs or parts by some of the methods stated above but in a few cases diseases are caused by the development of the pathogene between certain closely oppressed organs, between the glumes of cereals and grasses and between the outer petals of unopened buds.

Bacteria which actually penetrate the tissues may be : (a) *intercellular* or in the spaces between the cells; (b) *inter-vascular*, or in the water-conducting vessels of the xylem ; (c) *intra-cellular*, or within the interior of cells.

Action of Bacteria on Plants :

There may be a mechanical splitting, tearing or crushing due to the enormous multiplication of the bacteria within the confined spaces but the principal actions are of a chemical nature, some of the important being : (i) The separation of the cells from each other by the digestive actions of enzymes upon the pectic substances ; (ii) The production of enzymes which destroy starch ; (iii) The formation of injurious acids, alkalis or toxic substances which either inhibit physiological processes or actually kill the protoplasm by their poisonous action ; (iv) The production of substances which stimulate cells to abnormal activity.

Dissemination of Bacterial Diseases :

Bacterial diseases may be introduced into new environment or. spread from diseased to healthy plants in a great variety of ways Diseased plants may harbour the disease and serve as centers of infection when transported to distant points or when allowed to remain in fields or orchards. Some of the more important agents of transmission are : (i) seed, fruits, bulbs, tubers, grafts, cuttings and other propagating stock ; (ii) insects and other animal life including birds, mollusks and worms ; (iii) contaminated composts and manures.

(c) Parasitic Flowering Plants

Besides the diseases caused by fungi and bacteria there are a few flowering plants which are parasitic on other living plants. In the great majority of the cases the damage done is slight or the host plant is of little economic importance but there are a few instances in which they invade valuable crop plants and cause considerable monetary loss.

Some of these are parasitic on the roots of the host plant while others grow attached to the stem of the supporting plant. Some are devoid of chlorophyll and entirely dependent upon the host plant while others have more or less chlorophyll and are only partly dependent on other plants for foods or raw material.

The common flowering plant parasites may be conveniently grouped as follows :—

(1) *Stem Parasites* :

(i) Entirely dependent ......Cuscuta.
(ii) Partly dependent......Mistletoe.

(2) *Root Parasites* :

(i) Entirely dependent......Broomrape.
(ii) Partially dependent......Striga.

Fig. 18. Cuscuta on *Zizypus jujuba*.

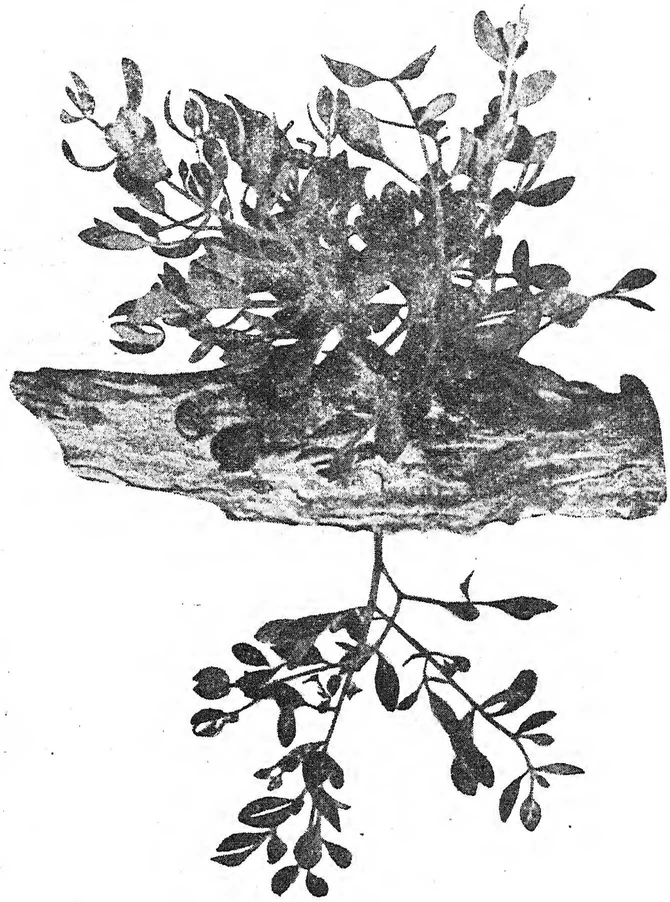

FIG. 19. Mistletoe on a branch of Mango.

Cuscuta :

Cuscuta (*Swaranalata*) is a slender twining vine with minute, rudimentary scale-like leaves and almost or entirely devoid of chlorophyll in all its parts. The colour of the plant is usually yellow. In some cases plants take on an orange colour and some species have a reddish or purplish tinge. The flowers are very small and occur in dense clusters. The plants are annuals reproducing by seeds.

The seeds germinate on the ground in spring and the young seedling is able to lead an independent existence only as long as the stored food in the seed is available. If the young *cuscuta* vine fails to come in contact with a congenial host plant about which it can twine, it soon perishes. In case it does find a host it soon establishes a parasitic relationship and continues growth until seeds are matured. The entwining vine puts forth parasitic roots in the form of suckers or haustoria which penetrate the tissues of the host and connect with both the water-carrying and food-carrying channels of the host stem. As soon as contact is thus established with the host the root and lower portion of the *cuscuta* vine perish, thus severing all connection with the soil and henceforth the parasite grows entirely upon the host plant and is wholly dependent upon it for sustenance.

Whenever and wherever found they should be collected before seeding and burnt. *Cuscuta* seeds will live in the soil for four or five years.

Mistletoe :

Mistletoes are shrubs with elongate slender branches; the leaves are opposite, narrow, tomentose, olivaceous, with short petioles. The flowers occur at the axils of the leaves and are solitary, slender, cylindric, of brownish-yellow or yellowish-white colour. They form seeds in berries which are surrounded by a sticky gelatinous matrix which enables them to cling tenaciously to the bark of trees. Birds eat the berries and are probably responsible to a certain extent for dissemination. In some species the seeds are forcibly ejected from the berries at maturity and stick to the bark of branches wherever they happen to lodge. On germination the hypocotyle forms a disc-like appressorium which flattens out against the host. From the centre of this disc a root-like sinker penetrates the tissues of the twig and establishes connection with the water-carrying tissues. When established cortical roots radiate in the bark of the host and send additional sinker into the wood.

The first noticeable effect upon the host after a mistletoe plant becomes established upon it is usually though not always swelling at the point of attack. Affected limbs first form fewer and smaller leaves, fruits which may be formed are dropped and the limb becomes unproductive. With time the limb dies back from the tip, and the

parasite assumes the form and appearance of the branch. Large branches and even trunks may be greatly deformed and the younger trees entirely killed.

They are commonly found on mango and other trees. The affected plants may be treated by breaking or scraping off the mistletoe plants and by pruning off small infested branches.

Broomrape :

Broomrape has been found on tobacco, brinjal and mustard plants. It is a small flowering plant of whitish colour and devoid of green leaves. There are no roots, but the underground portion of the stem sends out root-like organs called *haustoria* by means of which the parasite attaches itself to the roots of its host plant. The stem is unbranched and thick and succulent at the base. The greater part of it bears white flowers tinged with blue.

Its seeds are very small, like dust particles and are produced in large quantities from a single plant. The parasite reproduces by seeds and grows only in the presence of its host plant. The seedlings on becoming united with the host plant draw nourishment from it through *haustoria*. The host plant being thus deprived of its food is left to starve and in cases of severe attack the affected tobacco plants are killed.

The seeds can remain dormant in the soil for a long time. The parasite should be prevented from maturing its seed. The plants should be pulled out as soon as they come above ground and should be burnt at once. Rotation should be practised and susceptible hosts not grown on the field for a few years.

Striga :

Striga grows as a parasite on the roots of sugarcane and jowar plants. Its roots are closely connected with those of its host and by means of them it sucks up food from the latter. The affected plant loses much of its nutriment in this way and cannot grow properly. A large number of the parasite is generally found growing on a single jowar or sugarcane plant and each gives out 15 to 30 shoots. Badly attacked fields have a great many plants of the crop killed at an early stage and present the appearance of drought-stricken areas.

Striga has small narrow greenish leaves and grows to a height of 1 to 2 feet. It bears white tiny flowers which can be seen only after careful observation. If both the host and the parasite are dug out completely the connection of the roots of the two plants can be easily observed.

Striga first appears above the ground in July-August. Flowers come out in September and the parasite matures its seeds in small capsules in December. The seeds are very minute and get dispersed all

FIG. 20. Orobanchae on Tobacco.

FIG. 21. Striga on Sugarcane.

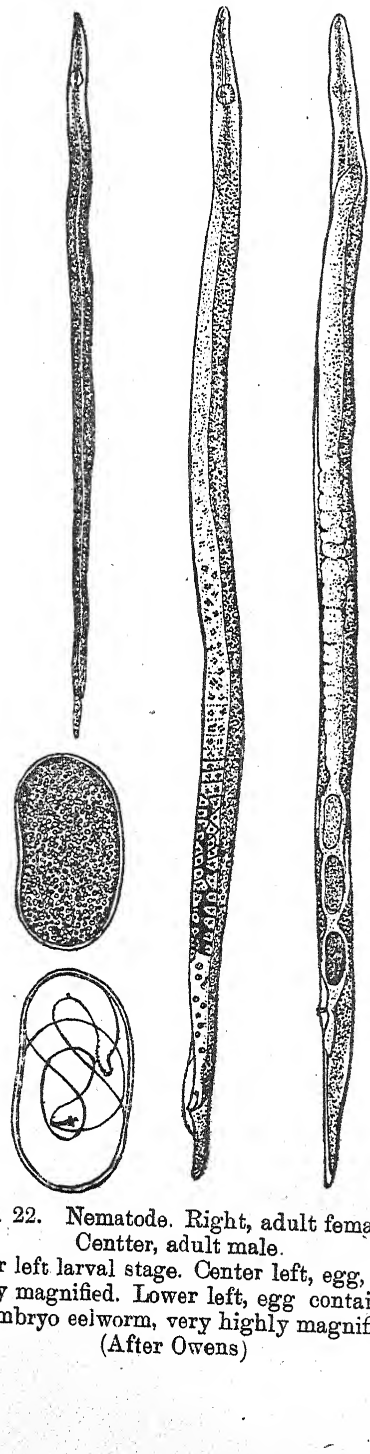

Fig. 22. Nematode. Right, adult female.
Centter, adult male.
Upper left larval stage. Center left, egg, very highly magnified. Lower left, egg containing an embryo eelworm, very highly magnified.
(After Owens)

over the field on the bursting of the capsules. Innumerable seeds of the parasite are in this manner dropped into the soil every year. Next season when the host crop is grown in the same field, the parasite comes up and attacks the crop.

In order to control the pest the parasite should not be allowed to form seeds. Before the formation of seeds they should be pulled out and burnt. Secondly, the field which has formerly borne an affected crop should be sown with a crop that is not susceptible to its attack.

(d) Nematodes

Amongst the animal parasites several such as insects, mites and microscopic animals (*nematodes*) live as parasites on plants. Insects and mites are serious plant pests. But these lie within the province of the entomologists. The nematodes are the cause of root troubles of scores of economic crop plants in nearly all parts of the world. Nematodes are so small that it is impossible to detect them without the use of the microscopes. They lay eggs about 1/250 of an inch in length. Within the egg the young worm develops, eventually escaping by the rupture of the shell. It is then about 1/75 of an inch in length.

The nematodes have tubular or filiform bodies with mouth and well-developed alimentary canal. The mouth is provided with papillae or lips or with hooks or spines in the oral or buccal cavity and leads to a narrow oesophagus, which usually has thick muscular walls and a cuticularised lining and may be dilated into one or more muscular oesophageal bulbs or pharynx. By valves and a muscular wall, the oesophagus pumps in fluid food as well as, in some species, solid particles and by peristaltic action, passes it on to the intestine usually a straight tube which opens near the posterior end of the body on the ventral surface

The body wall is muscular and encloses a body cavity containing the blood fluid, the alimentary canal and the excretory and reproductive organs. There is no definite circulatory system and respiration organs are lacking. The body is unsegmented, but the stiff cuticle is often ringed. The muscular body wall makes it possible for the body to be knotted, curved or bent and permits the characteristic undulatory movements.

The sexes are generally separate and the males smaller than the females. The females lay eggs but in a few cases they may bear living youngs. Many species are parasitic during either all or a part of their life cycle, and some animal parasites require two entirely unrelated hosts to complete their life cycle.

The plant pathologist is interested in but one family of the nematodes, the *Anguillulindae* (*Tylenchidiae*). This is a family of minute forms which live either free in the soil, decaying organic matter, water

etc ; or on or in plants as parasites. The nematode disease is not serious upon all species of plants, but it is no doubt injurious to some extent. In several instances no external evidences of the presence of these worms in infested plants are visible. But on examination of the roots of the plants a number of galls may be found. If these galls are cut across and examined under the microscope myriads of these tiny worms will be discovered.

II. Non-Parasitic Diseases

(a) Deficiencies of Soluble Salts

Every green plant requires ten different chemical elements for its proper nutrition. These elements are : carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron.

Carbon, hydrogen and oxygen are combined to form carbohydrates, which are essential foods for crop plants. In addition to these three elements, nitrogen, sulphur and phosphorus enter into the composition of proteins and nucleoproteins which are manufactured by green plants. *Potassium* is essential for healthy growth and accompanies and plays a part in carbohydrate synthesis. *Calcium* is necessary for normal leaf development ; it exists as calcium pectinate, in the middle lamellae which cement adjoining cells and may serve a protective action by combining with oxalic acid to form crystals of calcium oxalate, which are insoluble. *Magnesium*, if not an actual constituent, at least accompanies certain proteins and is contained in chlorophyll. *Iron* in minute amounts is essential for green plants and its lack prevents chlorophyll formation.

Elements likely to be Deficient :

Of all the essential elements cited above those which are most likely to be deficient in certain soils and to limit plant growth or give rise to abnormal or diseased conditions are nitrogen, phosphorus and potassium. Under certain conditions, sulphur, magnesium, calcium and iron may be lacking in the proper amount. The absence of an element or its presence in non-available form will lead to the same results :

(*i*) *Nitrogen shortage*: Aerial growth is very much restricted or dwarfed in much the same way as in water shortage or drought injury. The root is abnormally elongated. In pronounced nitrogen deficiency, the foliage may assume a light green to yellowish green colour and with chronic or continued shortage become dry and yellowish brown.

In many cases nitrogen shortage is expressed only by a lowered quality of the commercial product, or in more pronounced shortage by dwarfed plants and lessened production. The shortage of available nitrogen may cause modified flower development and consequent un-

fruitfulness. It is one of the factors that influences sterility and is also a factor in the premature dropping of fruits. It is also the belief that biennial or irregular bearing in fruit trees is largely due to a disturbed nitrogen relation.

(*ii*) *Phosphorus deficiency*: Some of the effects produced by phosphorus deficency are fading of the chlorophyll, burning of the blade in various locations, a reduction in leaf size, or a change to a dull browinsh-green colour without lustre.

(*iii*) *Magnesium deficiency*: The visible effect of magnesium deficiency varies from a mild or faint chlorosis to a pronounced chlorosis and in the more severely affected plants may cause internal or marginal necrotic areas or complete necrosis of the leaves, the symptoms developing progressively from the base upwards.

(*iv*) *Potash deficiency*: The general effects of shortage of potash may be noted: a reduced photosynthetic activity and consequently a retarded or dwarfed growth of storage organs, such as fleshy roots or tubers or in cereal crops the development of vegetative structures at the expense of the grains; in woody plants a suppressed or weak development of terminal shoots which may end in a 'die-back'; the appearance of yellowish, brownish or whitish sports in leaves at first near the margin and later more general if the shortage continues and is pronounced; the later blighting of the foliage and premature death if the shortage is not relieved.

Therapeutic value of some rarer elements:

In addition to the ten elements generally recognised as essential in the nutrition of plants, certain others which occur in the soil in relatively small amounts may have a corrective or therapeutic value for certain pathological conditions The exact way in which this corrective effect is accomplished is in many cases uncertain. Some of these trace elements such as boron, copper, manganese, zinc and others have been used effectively for the correction of certain diseases of our crop plants.

Boron has been successfully employed in curing 'bog disease', a trouble characteristic of swampy heath soils in European countries. Some of the crops affected are oats, barley, wheat, clover and turnips. Oats show a whitish green colour with increased stooling; barley, yellowing and marginal curling or rolling of leaves and empty heads; wheats, longitudinal white stripes on the leaves and heads rudimentary or lacking. The curative value of boron has also been demonstrated for the brown heart disease of turnips and swedes, cork and drought spot of apples and the crack stem of celery.

In certain cases of chlorosis copper has been shown to have a beneficial effect whether applied in the soil or sprayed on the leaves.

In some unproductive soils it has, on the other hand, been found to induce chlorosis.

A group of diseases similar to 'bog diseases' have been benefited by treatment of the tree or soil with zinc salts. Zinc salt treatments have also proved beneficial for the bronzing of tung trees in Florida, the pecan rosette in Arizona and the mottle leaf of citrus in California.

In manganese shortage marked chlorosis of the foliage is a symptom, with retarded growth, leaves reduced in size, blighting of terminal buds, and necrosis of leaves and defoliation. Some of these troubles at least are prevented by spraying or dusting with manganese sulphate or by soil treatments with manganese sulphate and sulphur.

(b) Excess of Soluble Salts

Certain types of growth are directly traceable to overnourishment, the first effect of which is to be seen in an increased vegetative development, a deeper green than normal, more succulent tissues and a retardation or suppression of reproductive functions. Generally over-nutrition leading to an excessive accumulation of plastic substances in the plant in proportion to their utilization may lead to pronounced morphological changes. Among these changes may be mentioned *phyllody*, or the transformation of floral organs into leaf-like structures; *Petalody* or the transformation of calyx bracts into petals; *pistillody* or the change of stamens into carpels.

(*i*) *Excess of nitrogen*: Some of the injurious effects of too much nitrogen are; delayed maturity, dropping of flower buds, a succulent growth with poor mechanical resistance, chlorosis of foliage, followed by burning or necrosis, browning or corrosion of the roots, gummosis and die back in citrus or stone fruits, lowering of quality in fruits or cereals and increase of susceptibility to parasitic diseases.

(*ii*) *Excess of lime or manganese*: In many cases the calcareous or manganiferous soil cause chlorosis by iron starvation. Sufficient iron is present but in lime chlorosis the excess of lime changes the iron compounds into insoluble, colloidal iron which cannot be utilised by the plant, or in the manganiferous soils to a much more difficultly available ferric iron.

(*iii*) *Excess of Boron*: Boron in small quantities may be beneficial but excess causes retardation or prevention of germination, death of plants or stunting so as to give imperfect and uneven stands, absence of normal colour marked by the bleaching or yellowing of normally green parts, especially the margin and tips of leaves, reduced growth and premature ripening with lessened yields.

(*iv*) *Excess of acid*: The first effect with moderate acidity will be retarted growth and a pallor or less intense green than normal, which if the unfavourable conditions continue may become more

pronounced. Foliage may become mottled, showing lighter green areas between the veins, or the chlorosis may become diffuse or general. Such affected plants may weaken and die prematurely or growth may be resumed if rain modify the acidity later in the season. Roots make a poor development and many of the lateral feeders may be repeatedly killed back.

(*v*) *Excess of alkali*: The effects of alkali will vary according to the concentration and kind of the salts present and the resistance or tolerance of the plant to alkali salts Some of the effects are failure of seeds to germinate, death of seedlings after reaching a few inches in height; retarded germination, the formation of sickly slender plants marked by chlorosis and early death without flowering or fruiting; retarded growth, chlorosis and some foliage burning but fruit ultimately reaching maturity. Established shade or fruit trees may show a retarded growth or dwarfing, short terminal shoots, leaves fewer and smaller than normal, and frequently showing much chlorosis, burning or blighting of leaves at the tip or margins and premature leaf fall.

Black alkali may cause a corrosion of the bark at the crown.

(c) Deficiencies or Excess of Water

(*i*) *Effects of Moisture deficiency*:—Shortage of moisture is marked by yellowing, reddening or other discolourations, followed by leaf fall in woody plants. In plants suffering from drought, dead brown areas may appear in the intercostal areas of leaves, in the center of areolae of these areas, or the leaves may be blighted or burned at the margins or tips. Moisture shortage by its interference with nutritive processes may lessen the production and storage of reserve food Tuber or root crops will remain small, and cereals will produce shrivelled grains. Fruits may be spotted, deformed or under normal in size or they may shrivel and fall prematurely.

(*ii*) *Effects of excess moisture* :—Excess of moisture is marked by yellowing and decomposition followed by decrease in production. An abundant water supply produces a type of growth that is more susceptible to the inroads of either bacterial or fungus pathogenes. The greater delicacy of the cell walls in plant structures provided with an abundance of water and the increased rate of growth frequently result in the rupture of organs, such as fleshy roots, tubers, stems and fruits. The fall of leaves, the shedding of blossoms, the dropping of fruits or the casting of twigs may sometimes result from a disturbed water relation, either an excessive supply, a shortage or abrupt fluctuation

(d) Improper Air Relations.

(*i*) *High temperatures* :—The principal types of heat injury are: retarded growth and undersize or failure to mature the flowers and fruit; localised killing of tissues or a sunburn or sunscald of leaves,

flowers or fruits ; localised killing of stem tissues or the formation of heat cankers ; defoliation or premature falling of leaves ; premature ripening of fruits and death of the plant as the result of a heat necrosis.

The scalding of flowers frequently results from high temperatures Many fruits suffer from sunscald or sunburn, especially those which are succulent. Even fruits like the apple may be severely burned, during periods of intensive summer heat.

Heat defoliation may occur in both deciduous and evergreen trees Seedlings of deciduous and herbaceous species may be seriously injured or even killed by high temperature, the injury being localised in the stem just above the ground level, thus resembling damping-off due to fungi.

(*ii*) *Low temperatures* :—As the temperature sinks below the *optimum*, growth becomes less and less rapid and finally ceases at the *minimum*. This retardation or checking of growth is the inevitable result of low temperature. A second effect of low temperature is the prevention of chlorophyll formation or the slower construction of this pigment, with the result that parts normally green may become yellow. In some plants or plant parts, cold causes the development of red pigment, which apparently obscures the lesser degree of chlorophyll development. When the temperature sinks to a sufficient degree, freezing of plant tissue results and death may follow, or, with the rise ef temperature the frozen tissues may thaw out without any appreciable injury.

(*iii*) *Frost Injury* :—The effects vary with the degree of cold and the sensitiveness of the plant and include: chlorotic bands or spots or general clorosis or yellowing; the formation of red pigment, *anthocyanin*, in organs normally green ; blistering, crinkling, curling, puckering, irregular laceration or shot-holing of leaf blades, sometimes with reduction in size ; and the partial or complete necrosis or blighting of leaves and vegetative shoots.

Blossom buds or blossoms may blight and drop without setting fruit or later frosts may affect fruit after it has already set and cause shedding, reduction in size, malformation, internal necrosis or sterility. The essential organs of the flower, stamens and pistil are generally more sensitive than the accessory parts.

(*iv*) *Light deficiency* :—The *optimum light income* denotes the amount of light which will induce the best growth or produce a type of development that is most nearly normal. As the light income drops from the minimum to zero or complete darkness, the plant may undergo gradual formative or structural changes, including alteration of colour and peculiarities of structure which are characteristic of the condition known as etiolation.

The changes which are characteristic of etiolation are : abnormal elongation of stems (internodes) and petioles or of leaves ; pronounced reduction in the size of the leaves ; reduction in the amount of chlorophyll or its complete disappearance (in darkness), suppression of the reproductive function, a soft or succulent type of growth.

(v) *Effect of intense light* :—With increase in the intensity of light photosynthesis will increase up to a certain point and then with further increase in intensity of light, the photosynthetic activities remain about constant, but for a short time only. If the intensity becomes too great or the optimum is exceeded for too long a period, the construction of carbohydrate food becomes less active and may finally be checked entirely. Under conditions of intense illumination, sensitive plants develop a pale or yellowish green cast or even a bronzing of the leaves.

The sensitiveness to intense light often varies with the age of the plant, for example the seedlings of many trees are not able to withstand the direct sunlight, while older trees suffer no derangements from exposure to the same light intensity. In the more sensitive species continued exposure to intense light may kill the protoplasm of cells in leaves, stems or fruits and browning, burning or blighting of localised spots or more extended areas may be the final result.

III. Virus Diseases.

Virus diseases of plants have during recent years attracted much attention. This is scarcely surprising for large losses on many crops are sustained annually as a result of their attack. In 1886 Mayer described and proved the infectious nature of a disease of tobacco which he designated as '*Mosaickrankheit*'. Six years later Iwanowski showed that the causal agent would pass through the porcelain bacterial filters. This was a new and startling discovery. Previous to this time such disorders had no doubt been attributed to physiological disorders or some environmental disturbance.

Host Plants : Of the virus diseases so far reported all have been on angiosperm host plants. Bacteria are known to be attacked by an enemy which is thought to be a living organism known as a '*phage*'. Among the angiosperms many of the families are known to be hosts for virus diseases. Included among the crop plants that are hosts to the disease are most of the cereals, all legumes, all of the *solanaceous* plants, peaches, bananas, beets, many of the flowers such as asters, lilies, etc. Members of the *Salanaceae* are especially susceptible.

Symptoms :

The foliage shows the symptoms of the disease first and the young foliage will usually show it much more pronounced than the older parts. In general the different types of symptoms attributable to viruses may be classified as follows :

(*i*) *Chlorosis* : Most of the virus diseases cause a change in the chlorophyll content of the leaf which is manifest in the different intensities of colour. Where this is great the leaf will have a patched or mottled appearance. The different colour areas may be irregular in shape or they may be quite regular in outline. In grasses they are more likely to be elongated, sometimes extending for some distance along the leaf. In some cases the entire leaf may become yellow.

(*ii*) *Distortion* : Distortion is one of the very common symptoms of many of the virus troubles. It consists of puckering, cupping, curling or rolling of the leaves in various ways.

(*iii*) *Necrosis.*—Some virus diseases cause certain parts of their hosts to become brown and shrivel. This is called '*necrosis.*' A necrotic condition of the phloem is very prevalent in potato plants affected with leaf roll.

(*iv*) *Dwarfing*.: Dwarfing and attenuation or abnormal slenderness are strikingly shown in witches' broom of potato and in tomato mosaic.

Types of virus diseases :

There are, generally speaking, three types of virus diseases :

(*i*) *Mosaic diseases.*—Symptoms are the mottling of leaves with or without malformation. They are transmitted by mechanical and biological methods.

(*ii*) *Yellow diseases.*--Symptoms are general chlorosis with clustering or upstanding habit of the young leaves. Transmissible only by biological methods.

(*iii*) *Miscellaneous.*—Various symptoms neither mosaic nor yellows. Transmission by either mechanical or biological method or both.

Theories about Cause :

The problem of determining the exact cause of the virus diseases has been a baffling one. Many theories have been propounded to account for the disease, to mention, the unbalanced nutrition theory, enzyme theory, bacterial theory, protozoan theory, virus theory. The virus theory is most generally accepted though the exact state of existence of the virus is not known. The term '*virus*' as used to-day includes the existence of an ultra microscopic organism or an infective principle of an unknown type in the expressed juices of an infected plant.

The term '*virus*' is borrowed from human and animal pathology. It has been used by animal pathologists for a long time to designate a contagium that cannot be definitely associated with a known organism. This infective principle seems to be too small to be seen by a microscope (*ultra-microscopic*), and in general not to be culturable by any of the methods known.

When the infectious nature of the plant diseases of this type became known through the discovery that some kind of an infective principle is carried in the juices of diseased plants the first impulse of course was to look for bacteria as the causal agent. But when persistent efforts failed to find bacteria the natural tendency was to note the striking resemblance between this type of plant disease and the virus diseases in animals and to adopt the term '*virus disease of plants.*'

Properties of viruses :

When a small quantity of the infective principle is introduced into a healthy plant, the virus is able to multiply or increase in amount. In this respect it resembles living organisms. It is readily transferable from the point of inoculation through the sap channels to other parts of the plant and as a rule after an incubation period of several days to a few weeks the virus is found in all parts of the plant.

The effects of many different chemicals have been tried. In general it requires rather strong solutions of the various chemicals to kill the virus. Nitric and hydrochloric acids do not render the virus inactive in concentrations of less than one gram in 50 to 100 cc. It requires a concentration stronger than one gram of potassium permenganate or zinc chloride in 100 cc. of water to kill the virus. Alcohol stronger than 55 per cent is highly toxic. Eighty per cent alcohol kills the virus in less than one-half hour. Four per cent formaldehyde is very toxic to the infective principle.

Temperatures near the boiling point quickly kill the virus. The virus is not so sensitive to low temperatures, being able to withstand a temperature of—180·C without losing its infective properties.

A virus extract will often remain active for a considerable period after separation from the plant. Ordinary tobacco mosaic will retain its activity for several years stored in a bottle but many viruses will not tolerate even a few minutes separation from their hosts.

Transmission :

Virus diseases may be disseminated in many ways, *i.e.*, through seeds cuttings, tubers and other propagating parts, through insects.

Although most virus diseases are not transmitted by seeds from a diseased plant a considerable number find their way into the seeds which then produce seedlings, of which a certain percentage may be

diseased. Bean mosaic is most readily transmitted by seed, but rarely reproduces more than 50 per cent of diseased seedlings Leaf roll of potato, lettuce mosaic, cucumber mosaic, tomato mosaic, etc., are transmitted by seed.

All the cuttings, tubers, scions and divisions made from a diseased plant carry the virus Vegetative propagation of plant provide conditions for the very rapid and complete spread of virus diseases.

The activity of insects in spreading virus diseases is now well established and it is known that aphids, jassids, capsids, leaf-hoppers, grass-hoppers and other families are capable of playing this part. A particular species of insect may be capable of transmitting more than one virus disease.

A good deal of doubt still exists as to whether viruses can be transmitted through the soil, although positive statements to this effect have appeared from time to time in the literature. On the whole, soil transmission probably plays a very small part in the general spread of plant viruses.

Economic Effects :

The economic significance of virus diseases varies greatly. They may cause severe damage to our market crops. Tobacco may be depreciated about 55 per cent in yield and quality together. In sugarcane the losses have been reported as high as 70 per cent in India. Sugar beet losses in America amount to 75 per cent. The greatest damage caused by virus diseases is perhaps the effect of the so-called '*degeneration of the potato*' crop.

Chapter IV

CONTROL AND PREVENTION OF PLANT DISEASES

The practical agriculturist is primarily interested in protecting his crops from diseases and usually cares little about the cause of the trouble provided he can find an efficacious remedy. The latter statement is true until he is made to realise that the most efficient control measures usually are based on accurate knowledge of the nature of the trouble. The more a cultivator knows of the causes and action of the disease the more intelligently and the more successfully will he be able to combat it. In early times the remedies recommended were necessarily empirical since nothing was known of the cause of disease in most cases. Even today we are using many control measures that originated empirically, however much we have modified and adapted them in recent years in accordance with our increased knowledge of the cause of the disease. With the gradual acquisition of more accurate information on the nature and cause of diseases we have worked out methods and devices to meet the special need in combating any particular disease.

Economic Importance of Plant diseases:

The number of plant diseases is very great, and even if those occurring on non-economic plants are ignored, there is still a large residue. A glance at the disease lists of economic crops such as are published from time to time by departments of Agriculture and other bodies will show as many as twenty or so diseases occurring on particular species of cultivated plants The majority of these appear for the present at any rate to be of little economic importance but one may say generally that more or less all cultivated plants are subject to two or three diseases of major importance which at various places interfere seriously with their profitable cultivation. Thus in the case of the potato one may cite four important diseases, blight, scab, rot and virus diseases all of which offer serious problems to the grower. In any one year and in a given locality certain of these diseases may do little damage or may even appear to be absent but over a wide area and over a period of years the aggregate loss is very great.

Estimates have been given of the total loss due to plant diseases in various countries In 1891 the loss of wheat, rye, oats and barley from rust in Prussia has been estimated at over three hundred million rupees. In Australia in 1890-91 the loss by wheat rust was estimated at 36 millions of rupees. Fungus disease has practically exterminated the coffee plantations of Ceylon where the loss from 1870 to 1886 was about 15 million rupees annually. The minimum loss India suffers annually due to wheat rusts has been calculated to be Rs. 40,00,000. The potato blight disease caused famine in Ireland in 1845-46. The diseases of *pan* has been estimated to cause a monetary loss of more than Rs 15 lacs a year in the Surma Valley.

Estimates by the plant disease survey of the United States Department of Agriculture indicate that approximately one bean in every dozen, one apple in every seven, one peach in every eight, one bushel of Irish potato in every twelve, and one bushel of wheat in every ten are destroyed annually by diseases in the crops.

From what has been cited above it will appear that monetary losses due to plant diseases are of enough significance to justify an intensive study of their causes and the means of controlling them.

How plant diseases cause injury and losses:

Types of injuries and losses caused by plant diseases are varied; the principal ones are stated below :—

(*i*) *Killing of annuals and perennials*:—In our annual crops such as cereals and other field and forage crops, garden vegetables, etc. killing during the juvenile stage may result in thin stands or even such a complete kill as to require reseeding or replanting. In other cases premature death may come at varying time before maturity but frequently sufficiently early to prevent harvesting of the desired crop,

or to reduce the yield. This may be illustrated by the killing of nearly mature *arhar* plants by wilt.

The loss of perennial plants like orchard crops which require a long period to reach the producing stage is more serious. Fungus root rot may destroy an orchard in 3-4 years.

(*ii*) *Reduction in productiveness of perennials* :—Certain diseases of perennial plants may not be sufficiently virulent to kill the affected plants outright but rather leave them to grow in a dwarfed or crippled condition for a period of years, sometimes completely ruined from the standpoint of production or in other cases with a greatly lowered yield, perhaps of inferior quality.

(*iii*) *Reduction in yield* :—The effect of disease upon the yield of the marketable product may vary all the way from only a slight reduction to a complete failure without causing the death of the affected plants. Many cases of reduced yields as a result of disease pass unnoticed by the grower or the amount of damage is often underestimated. Cereals may suffer serious reductions in yields from smuts and rusts as well as marked reductions of grade or quality.

(*iv*) *Lowering of grade or quality* :—The marketable product from various crops may be lowered in grade or quality from various defects caused by parasitic organisms acting directly or indirectly or by injuries resulting from non-parasitic agencies. Fungus lesions including scab fruit spots, blotch, rust, rot, may lower the quality.

(*v*) *Destruction of the market product previous to harvest*:—Fruit crops, truck crops and other crops represented by fruits, tubers, bulbs corms and fleshy roots or other storage organs which are reserves of food material are subject to rapid decay. Some of these preharvest rots may continue in the harvested crop and cause heavy losses during storage and during transit to market. The smut diseases of cereals, especially of wheat, oats and barley offer striking illustrations of the destruction of the market product, the grain, previous to harvest.

(*vi*) *Losses in storage or in transit to market* :—Certain diseases of fruits and vegetables begin their attacks in the field previous to harvest and continue to develop during storage or during transportation to market while certain others are confined entirely or almost exclusively to the harvested crop and make their appearance at various stages of the storage period. Storage and transportation losses may be heavy in citrus, pineapple and bananas.

I. Control of Parasitic Diseases

A knowledge of the life history of parasitic organisms is of fundamental importance especially in the adoption of a programme of protection. Throughout the early history of biological sciences, before it was known that parasitic organisms pass through various stages, pro-

gress in diseases control was slow and was dependent largely on empirical practices or blind trials. A knowledge of the life history of parasites makes it possible to discover weak or vulnerable points if any exist and to strike at the proper time and place. Without a knowledge of life histories we might still be trying to control smuts by spraying, rusts by seed disinfection, downy mildews by soil sterilization. It is true that some very important advances have been made in disease control by accident but during the more modern development of plant disease studies, effective control has depended more and more on planned scientific investigations. A striking illustration is afforded by the study of the life-history of the organism causing the brown rot of lemons It was shown that the causal fungus produced swarm spores which were liberated in the washing tank through which the fruit passed and that protection was afforded by the use of fungicides added to the wash water. Modern plant pathology presents many other examples in which effective control has been based on life-history studies.

The means adopted for controlling parasitic plant diseases are as follows

(*i*) *Sanitation* : A great many plant disease organisms winter over or are perpetuated for a short time at least on various forms of plant debris. The brown rot and bitter rot fungi hibernate on rotted and mummified fruits. Many fungi and bacteria survive in the prunings that are left in the soil. All such diseased debris should be burnt or destroyed in some way.

(*ii*) *Crop rotation* : Many pathogenic organisms harboured in the soil are parasites to certain species of crop plants. If these certain crops are not grown in a field for a few years the special parasite of the crop will die out in that field. It will then be safe to grow the susceptible crop again in this soil. The length of time an organism will survive in the soil in the absence of its host plant determines the length of the rotation cycle.

(*iii*) *Surgery* : (cutting out diseased parts) : Many of the canker diseases, as fire-blight, European canker and apple tree anthracnose can be fought more or less successfully by cutting out the diseased areas. Such parts should be destroyed by burning or by other means after separation from the host.

(*iv*) *Roguing* : (uprooting and removal of diseased plants) : This method is usually practiced with truck and vegetable crops. It can be successfully used against those diseases which can be easily recognised in the field during the growing season, for example, wilt diseases of potato. Such removal completely or partially checks the further progress of the disease.

(*v*) *Removal of alternate host* : Fungi which are heteroecious complete their life cycle on two types of hosts. Wheat rusts for-

example is known to pass a part of its life on wheat and the rest on barberry in some countries. In such cases one means of combating the disease consists in the eradication of the alternate host.

(*vi*) *Destruction of weed hosts* : Many parasites causing disease of economic plants also attack other related plants which are weeds or of no economic importance. The *Rhizoctonia* fungus which attacks a large number of plants is also known to attack a wide range of weeds. The destruction of these weeds or non-economic hosts is to be recommended as one means of combating these diseases.

(*vii*) *Sterilization of soil*: Plant disease organisms which live in the soil can be controlled by sterilizing the soil. Soil sterilization can be done by steam, heat or chemicals.

(*viii*) *Sterilization of tools* : In cases where diseased parts of plants are cut off it is recommended that the tools be sterilized between cuts to prevent carrying the germs from diseased tissues and depositing them on healthy tissues or plants. During pruning of trees many healthy plants get diseased, the disease causing germ being taken from diseased plants to healthy ones through the pruning instruments.

(*ix*) *Disinfection of containers* : In cases where the pathogene in the form of spores or bacteria separates from the host and adheres to containers, carriers or storage bags or bins, there is danger of contaminating the next batch of products placed in such containers. Therefore the containers or carriers should be disinfected before filling again. This will apply to grain sacks which have held smutty grains, boxes or crates in which produce has moulded or decayed and railway cars.

(*x*) *Disinfection of wounds* : Wounds that occur naturally or due to pruning or removal of diseased parts in plants should be covered with a fungicide in order to avoid infection by fungi or bacteria. Many fungi and bacteria make their entrance into plant body through wounds.

(*xi*) *Seed disinfection*: —Disinfection of seed and other propagating parts of plants are important methods in controlling plant diseases. Seeds may be treated by hot water or fungicides before sowing; this will kill the living spores or mycelium of the parasite in the seed without injuring the viability of the seed.

(*xii*) *Changing the soil reaction* :—The acidity or alkalinity of the soil sometimes exerts a strong influence upon plant pathogenes which live in the soil or attack the underground parts of plants. If a certain organism thrives best in an acid soil it may be combated by changing the reaction of the soil by the addition of lime. If it is an organism which is favourably influenced by an alkaline soil the control procedure may be reversed and the soil treated to render it less alkaline.

(*xiii*) *Application of fungicides* :—Fungicides are used to a considerable extent for controlling plant diseases. Fungicides are of greatest benefit in combating parasites which live on the surface of the host plant *i. e.*, the *ectoparasites*. But the plants can be protected from the attack of air-borne parasites by the use of fungicides. The object aimed at here is to cover the surface of the plant with a thin but more or less continuous film of the fungicidal substances so that when the air-borne spores of the parasite arrive they are unable to initiate attack.

(*xiv*) *Growing of resistant varieties* :—Some varieties of plants are less susceptible to a specific disease than other varieties. World over plant breeders are constantly trying to find disease resistant varieties by breeding and selection Some varieties of wheat are known which are more resistant to rusts and smuts than other varieties. Other things being equal the more resistant varieties should be grown.

(*xv*) *Selection and sowing of clean seed*:—Where disease on seeds can be detected readily enough it is sometimes possible to sort out the diseased seeds and separate them from the healthy ones. Bean seeds affected with anthracnose or potato seed tubers affected with scab may be easily sorted out. But this method is not entirely satisfactory as some of the seeds which are slightly affected are likely to escape notice. But bean or other seeds may be safely collected from a field or locality where the disease does not occur.

II. Control of Non-Parasitic Diseases

Non-parasitic diseases of plants which are due to unfavourable physical and chemical conditions of the soil or due to unfavourable atmospheric conditions can be mitigated by modifying the environmental factors. The soil characters can be changed to a certain extent but it is almost impossible to change atmospheric condition.

Unhealthy water relations can be controlled by ploughing, addition of organic matter, green manuring, irrigation and proper drainage.

Diseases which are due to lack of certain nutrient elements can be corrected by supplying those elements in available forms in the shape of fertilizers and salts. Troubles that are due to excess of certain elements or salts can be corrected by applying substances that will neutralise their effects.

III. Control of Virus Diseases

Prevention of mechanical transmission, eradication of weed hosts, use of disease-free seeds and propagating parts, rogueing out of diseased plants, rotation of crops, indexing of seeds, spraying for the control of insects, are some of the important methods to be followed in controlling virus diseases.

Disease resistant plants appear to give the most promise of control and in the case of sugarcane, bean, spinach and cucumber resistant strains have been developed.

Chapter V.

FUNGICIDES : SPRAYING, DUSTING AND PAINTS.

The term *fungicides* broadly considered is any substance used to kill or to prevent the growth of fungi, including bacteria. According to their mode of action, it is possible to classify fungicides into two groups : *direct* and *protective*. The direct fungicides kill through contact with the fungus on the plant surface while the protective fungicide prevents the establishment of fungal infection.

Fungicides, to be effective, must fulfil two conditions Firstly, it must be effective, against the fungus against which it is applied, yet should cause no injury of economic importance to the host plant. Secondly, it is necessary that the toxic material be amenable to application in an effective manner ; the direct fungicide must make contact with the fungus to be destroyed, the protective material must leave a deposit of satisfactory protective properties. The methods of application of fungicides to the growing plant are conveniently classed on a physical basis thus :

(i) *Spraying* :—When the toxic agent is applied in liquid form as a solution, suspension or emulsion ;

(ii) *Dusting* :—When the material is applied in the form of a finely divided powder.

1. Spraying.

The grower should bear in mind that spraying is not a panacea for all troubles but only one of the important measures for use against certain plant diseases. Spraying in the sense here employed consists in the application of fungicide in water as a carrier in the form of a fine mist to the aerial parts of plants. Any chemical compound or mixture selected for the prevention or treatment of plant troubles by spraying should fulfil the following specifications :

(i) It should be sufficiently concentrated to have a killing or inhibiting effect upon either dormant spores, germinating spores or upon mycelium.

(ii) The ideal spray should not injure or disfigure the plant surfaces to which it is applied.

(iii) The spray should stick to the parts to be protected and should cover the surfaces with a uniform film which should not be easily washed off after drying.

(*iv*) The active principle should be soluble or capable of change to a soluble or diffusible form under the influence of atmospheric conditions.

Materials for spraying :

Very many substances have been used for spraying in the past and the number still employed in certain localities and under specific conditions for certain valuable crops, such as the potato is considerable. For practical purposes the list may be reduced to a few that have proved applicable under very varying conditions and that have established themselves as efficient when properly made and employed, in a large number of cases.

(*i*) *Bordeaux mixture* : —This is the earliest, the most widely known and the most generally useful of all spray fluids employed against parasitic fungi.

The formulæ used for preparing the mixture vary considerably and it cannot be said that there is any general agreement as to the best to use. The chief strengths recommended are:

(1)	Copper sulphate	... ...	4 lbs.
	Quick lime	... ...	4 lbs.
	Water	... ...	50 gallons.

This may be selected for general use on fruit trees (except peaches and on most field, garden and planters' crops.

(2)	Copper sulphate	... ...	5 lbs.
	Quick lime	... ...	5 lbs.
	Water	... ...	50 gallons.

This is much used in general spraying and is often known as one per cent Bordeaux. A two per cent solution in which the amount of copper sulphate is doubled without increasing the other ingredients is advocated for spraying potatoes against blight in some countries, and the same with the lime also doubled is used against koleroga disease of the arecanut in Mysore.

Preparation of Bordeaux mixture :—To make the mixture, dissolve the copper sulphate in half the water, in a wooden vessel, by suspending it in a piece of gunny sacking just immersed. It dissolves slowly and may conveniently be put in overnight. Then slake the lime in a second vessel with a few pints of water added little by little until the bubbling ceases, after which pour in the rest of the water. Then mix the two solutions together either by pouring one into the other or the two together into a third vessel. Pour the lime through a strainer to keep back all lumps and stir the mixture all the time while pouring. Stir and strain again when pouring into the sprayer.

Bordeaux mixture as generally prepared is alkaline, containing an excess of lime and turning red litmus paper blue. An excess of copper compounds is dangerous to the foliage of many plants and is indicated by the solution turning blue litmus paper red Another way of determining if the mixture contains an excess of copper is to immerse a bright iron or steel surface, such as a knife blade or a nail, in the upper layer of the liquid, when a deposit of copper will form on the metal if the mixture is unsafe.

Bordeaux mixture deteriorates very rapidly upon standing. If for any reason a quantity of spray is made up and cannot be used within a few hours it may be preserved in good condition for an indefinite time by adding a small amount of common sugar, one ounce for every eight pounds of stone lime or 10 lbs. of hydrated lime in the spray.

(*ii*) *Bordeaux mixture with resin* :

Washing soda	1 lb.
Resin	2 lbs.
Water	1 gallon.

Boil the water, then add the soda. When dissolved, add the resin and boil for about an hour stirring continually. Add this when cool to Bordeaux mixture prepared as above at the rate of one gallon to every 24 gallons of Bordeaux.

This mixture has given good results in the spraying of areca palms for koleroga as the resin increases the adhesiveness to a marked degree. A weaker solution containing only half as much resin has also proved to be superior to ordinary Bordeaux in spraying potatoes in the Khasi Hills. In both the cases spraying has to be carried out during the period of heavy rain.

(*iii*) *Burgundy Mixture* :—This mixture may be substituted for Bordeaux mixture in localities or situations where it is impossible to obtain good lime. Its fungicidal value is considered about equal to Bordeaux mixture and it does not leave so much colour on the foliage or fruit as does the latter. It probably does not adhere so well through rains as Bordeaux.

Copper sulphate	10 lbs.
Washing soda...	12½ lbs.
Water	50 gallons.

This is the standard mixture which is extensively used against potato blight in Ireland with excellent results.

Make up exactly as in Bordeaux mixture, using soda instead of lime. The materials used should be guaranteed 98 per cent pure. Test as before with blue litmus paper and add more soda solution

if it reddens. Excess of soda may cause scorching, and can be detected by red litmus paper turning blue, in which case more copper solution must be added.

(*iv*) *Ammoniacal Copper Carbonate*: In spraying fruits nearing maturity with Bordeaux mixture an unsightly deposit is usually left on the fruit. In order to avoid this undesirable result this spray was devised. It is not usually as effective as Bordeaux but in some cases it may be desirable to use it in order to escape the bad effects of Bordeaux. The usual formula is as follows:

Copper carbonate ...	5 or 6 oz.
Ammonia	3 pints
Water	50 gallons

To prepare this spray first dissolve the copper carbonate in the ammonia and then add the water.

(*v*) *Lime sulphur solutions*: It has been found suitable in orchard practices and against the powdery mildews. Concentrated lime sulphur solutions made by commercial firms are sold in barrel lots or smaller amounts. These solutions are diluted on a basis of a test of 32 Be., which is the usual standard of concentration. For fungicidal purposes these are used at a strength of 1 gallon in 25 to 30 gallons of water.

Success in spraying:

The success of a spraying done to control or prevent a particular disease will depend on:

(*i*) The selection and use of the proper fungicide. The crop to be protected and the parasite to be eliminated must be given consideration in making the choice since our crop plants show great variations in sensitiveness to injury from sprays and the different parasites exhibit various degrees of tolerance to poisons.

(*ii*) The application of the spray at the right time. The timing of applications and their number can be regulated only by a knowledge of the life-history of the parasite.

(*iii*) The thoroughness of application or the complete coverage of the surfaces to be protected, whether twigs, leaves and fruits.

Cost of spraying:

Cost of spraying will be governed by the prevailing prices of the spraying materials. In any spraying it is necessary to consider whether the cost of spraying will pay for the benefit that will be derived afterwards. If it is found uneconomical it is better not to give it a trial.

Spraying Apparatus :

The selection of spraying apparatus is a subject upon which no extensive advice can be offered. It is best left entirely to the ingenuity of the plant grower. There are in general three kinds of pumps in common use. Bucket pumps are made for use with small amounts of the fluid in ordinary buckets. They are intended for small gardens but are not convenient for extensive sprayings.

Knapsack sprayers are equipped with straps so that they may be carried on the back and are so arranged that the operator pumps with one hand and holds the nozzle with the other. They are suited for more extensive work and are used for low shrubs or potatoes.

Compressed-air hand sprayers are small capacity sprayers comparable in use to the knapsack types. This type consists of a cylindrical tank with the central pump, which compresses the air, thus forcing the spray out under pressure.

The barrel pumps are large pumps intended for attachments to barrels. They possess more general usefulness than either the knapsack or bucket pumps on account of the greater amount of fluid carried and the capacity for work.

II.—DUSTING.

Fungicides that are applied dry in the form of powder are known as *dusts* and their application *dusting.* Compared with spraying dusting has certain advantages and disadvantages. They are :

Advantages of dusting.—(*i*) Requires less time for application. Some claim it takes only 1/5th as much time as spraying ; (*ii*) Requires no water. This is quite important an item when water is scarce or not near at hand ; (*iii*) Labour cost for application is less ; (*iv*) Difficulties of preparation are reduced ; the dust may be purchased ready for application, the expense of time and labour for preparation and the cost of mixing vessels disappears ; (*v*) Simpler and lighter apparatus for application is required.

Disadvantages of dusting.—(*i*) Materials cost more per acre than sprays ; (*ii*) In many cases dusts are less effective than sprays ; (*iii*) Dusts are more difficult to apply satisfactorily in windy weather.

Materials for Dusting :

(*i*) *Sulphur.*—Sulphur is most commonly and widely used. It is used in the finely divided form known as 'flowers of sulphur,' chiefly against the powdery mildews. The toxicity of a sulphur dust is influenced by the size of the particles which should be at least fine enough to pass a 200-mesh sieve ; many of the commercial brands are still finer. It is convenient for garden use, but is likely to be replaced

in field practice by the lime sulphur combinations. It should be dusted early in the morning when the leaves are still damp from dew, as it adheres better than if the leaves are dry. The best results are got on fine dry days while rain is injurious as the powder is readily washed off.

(*ii*) *Copper dusts.*—Copper-lime dusts have been used as substitute for the copper-containing sprays like Bordeaux or Burgundy. These are composed of 5 to 25 per cent of a dehydrated or monohydrated copper sulphate with a dilutent, generally hydrated lime. In some trials the copper lime dusts have given as good control as spraying but the majority of comparative tests have shown them to be decidedly inferior.

Types of Dusters :

With the development of dusting as one of the recognised methods of applying fungicides dusters are now available from the simple powder gun to the portable power dusters. These are designed to meet the same needs as the sprayers and include simple shakers, bellows, dusters, powder guns or plunger dusters and machines with fan blowers including small hand or crank dusters, sprocket power machines for attachment to a cart or light wagon and special traction power dusters for truck or field crops.

When to apply the Fungicides :

Most fungicides are used to prevent infection by covering the healthy parts of the plant with a fungicidal layer. They are usually applied when the plant is in leaf, the first application at or just before the period when the disease appears, and others often enough to replace the fungicide when it gets washed off by rain, or begin to lose its effect or when new leaves are formed that require to be similarly protected. If rain falls before the fungicide has properly dried on the leaves, say within 12 to 24 hours, much may be lost and an early repetition may become necessary. Hence applications of fungicides should be done where possible in dry weather and as early in the day as practicable.

III.—PAINTS

Various paints are used to protect tree wounds so that pathogenic fungi or bacteria do not gain entrance into the plant body through these wounds. The most commonly used ones are :

(*i*) *Bordeaux Paste* :—One of the best dressings that has been devised to protect tree wounds against infection by wood-rotting fungi is Bordeaux paste. This contains the same ingredients as Bordeaux mixture but with much less water in proportion to copper and lime.

The usual formula is :—

Copper sulphate $1\frac{1}{2}$ lbs. in one gallon of water.
Quicklime 3 lbs. slaked in one gallon of water.
Mix in equal parts.

This makes a paste which is applied to the wound in the same manner as white wash.

(*ii*) *Grafting Wax* :—A useful grafting wax for covering tree wounds and top working is made either by melting equal parts of beeswax and resin or by using 4 parts of resin, 2 parts of beeswax and half part tallow. This is a very effective paint for keeping away fungus spores and bacteria.

(*iii*) *White Wash* :—Its common use is for the covering of the trunk and large limbs to prevent sun-burning, especially when the trees are severely pruned or when they may be considerably opened up for treatment of diseases.

A formula to prevent sunburning of trees is :—

Hydrated lime	50 lbs.
Water	8 gallons
Salt	4 lbs.

Chapter VI

SEED TREATMENT

In the majority of cases the parasite is carried either on or within the seed : (*a*) as spores lodged upon the surface or developed in the interior ; (*b*) as the vegetative body of the parasite, *mycelium-bacterial cells*, or *nematodes*, either external or internal and (*c*) as *sclerotia* or resting bodies on the surface or sometimes within vegetative reproductive structures as may be illustrated by the *Rhizoctonia* disease of potatoes and by certain bulb diseases.

The diseases that are transmitted through seeds are attacked in seed treatment Enormous number of methods of seed treatments have been tried. They may be conveniently dealt under two heads : *chemical* and *physical*. Many of the methods have not found general adoption. Some of the features demanded to insure general adoption are :

(*i*) A reasonably low cost ;

(*ii*) No injury, or but slight injury to the seed when used at the strength required to kill the pathogene ;

(*iii*) An easy or relatively simple method of application.

I. Chemical Methods

The object here is to treat the 'seed' with some chemical which will prove toxic to or prevent the development of the resting stage

of the pest without injury to the germination or growth of the 'seed'. The principal chemical compounds or mixtures which are in general use are as follows :

(*i*) *Copper carbonate :* It is on the market in two strengths : the pure copper carbonate containing 50 to 54 per cent metallic copper ; and the diluted mixtures containing 16 to 20 per cent metallic copper. Some of the advantages of copper carbonate for the treatment of wheat are that it causes no seed injury and that wheat may be treated months before needed for seed without any decrease in effectiveness. It is not recommended for other cereals but has been used effectively for the control of damping off of miscellaneous garden vegetables. For wheat 2 to 3 ounces per bushel is effective.

(*ii*) *Corrosive sublimate :* One of the objections to its use has been its extreme toxicity to man and animals. It has continued, however, to be a standard treatment for potato tubers, sweet potatoes and bulbs of flowering plants. Three slightly different formulas have been employed: the cold or standard solution or steep, generally 1 ounce to 7½ gallons of water (1 to 1,000) or sometimes stronger, 1 ounce to 6 gallons ; the hot solution used at either standard or double strength for 5 minutes at 120° to 122° F and the acidulated mercuric chloride of standard strength plus one per cent hydrochloric acid (1·10·1000) for one hour or for 5 minutes in a stronger solution (1-10-500).

(*iii*) *Inorganic compounds of mercury :* A number of inorganic mercuric compounds under different trade names have been placed on the market for seed treatments. Some of these contain the following besides mercuric chloride : sodium chloride (*Fusafine*), *formaldehyde* (*Sublimoform*), copper sulphate (*Weizenfusariol*), phenol and alcohol (*Betenal*). Some of the other inorganic mercury compounds used are: mercuric iodide (*Alavit B*), mercury rhodanide (*Urania*), and a mercury-copper-arsenic compound (*Tillantin C*). The directions for their use are furnished by the manufacturers along with the products. Some of these have been found very effective.

(*iv*) *Organic mercury compounds*: Various preparations with the main active constituents in the form of organic mercury compounds combined with dilutents and stabilizers have been placed on the market some for use in liquid form, others as dusts. They have been marketed under various trade names, some of which are: *Chlorophol*, *Ussulun*, *Semesan*, *Germisan*, *Ceresan* and *New Improved Ceresan*. The directions for use of these compounds are furnished by the manufacturers along with the product. Many of these compounds have been found very suitable and effective materials for seed treatment.

(*v*) *Formaldehyde* : Formaldehyde is a gas and is available on the market in a 36 to 40 per cent aqueous solution. It has been extensively used for the control of stinking smut of wheat, oat

smuts and the covered smut of barley and for potato tubers, especially for the control of common scab. It has been used both hot and cold; the principal formulas being 1 pint to 30, 40, 50 or 60 gallons of water for the cold dips.

Methods of Chemical Disinfection :

Seed may be subjected to the action of the chemical in a variety of ways :

(*i*) *Sack method* : This is adapted to treating either small quantities of seed in muslin or cheese-cloth containers or larger quantities in partly filled gunny bags. The seed is dipped for the requisite length of time in the fungicide of desired strength and drained and planted at once or, if necessary, given an approved after-bath to reduce seed injury.

(*ii*) *Open-tank method* : The seed is emptied into an open barrel, tank or vat of appropriate size containing the treating solution. The seed is allowed to remain in the solution for the specified length of time after which the solution is drained off. One advantage of the open-tank method for cereals is that it makes it possible for the operator to skim off the bunt balls and the light seed.

(*iii*) *Sprinkling* : This method is mainly applicable to formaldehyde disinfection. The grain is sprinkled with the solution of requisite strength, shovelled over to distribute the moisture evenly; then piled and covered with a tarpaulin or sacks for 2 to 5 hours before drying.

(*iv*) *Dusting* : This method is used in applying the dry powdered materials. The fungicide in a very finely divided form is applied in such a manner as to coat the seed with a fine film of dust particles.

II. Physical Methods.

Hot water treatment is effective for external seed-borne parasites but the method is so cumbersome that it is not employed when chemicals are effective. It is mainly internal parasites which demand the use of heat as therapeutant.

(*i*) *Disinfection by hot air* : Hot air treatments are effective for killing the internal mycelium of the late blight fungus in potato tuber but the method is too cumbersome to be adopted for general use A temperature of 40° to 49°C for 4 hours or 30°C for 65 hours is effective. Effective elimination of anthracnose from cotton seed has been accomplished by a predrying at 122°F for 36 hours or at 140°F for 24 hours followed by an exposure of 8 hours at 205°F with little or no decrease in germination.

(*ii*) *Disinfection by hot water* : The most careful procedure in carrying out the hot water treatment has been employed in the treatment of wheat or barley for the loose smuts. This comprises

(*a*) presoaking to initiate fungus growth ; (*b*) pre-steeping in hot water a few degrees below the treating temperature ; (*c*) immersion in the bath at the selected temperature and for the requisite time ; (*d*) immersion in a cooling bath to prevent seed injury by too long action of the heat ; and (*e*) drying of the seed by spreading out. The selected temperature for immersion varies from 118 to 129°F. for the different seeds.

Chapter VII.

SOIL DISINFECTION.

Many plant pathogenes, fungi, bacteria and nematodes spend a part of their life cycle in the soil and invade any suscept when opportunity offers. Many of the diseases caused by these soil-infesting organisms can be prevented by soil disinfection while others must be handled by other methods.

Soil disinfection as a means of disease control is rarely practical for extensive field plantings but can very successfully be employed for sterilizing soils of seedbeds.

Disinfection may be carried out by (i) *physical* and (ii) *chemical* methods.

I.—Physical Methods.

In the physical method heat is the principal agent and it may be furnished by oven baking, direct firing, hot water, flame thrower, some electric device or steam. In all cases of heat treatment the operation must be carried out previous to planting.

(i) *Direct firing* : This is a primitive method. It is carried out by burning straw, plant refuse or wood on the ground to be sterilized. It has been found sufficiently effective when burning is done thoroughly and carefully.

(ii) *Hot water* : It has been used effectively for eelworms and certain fungi in pots or boxes. Submersion of the pots for 5 minutes at 98°C, drenching with boiling water have been reported not only to control the disease but also to increase germination, to prevent damping off and to increase the size and vigour of the seedlings.

(iii) *Steam* : Methods for sterilizing the soil with steam have been devised and developed in foreign countries but their applications are limited on account of prohibitive costs, and complications of operation.

(iv) *Flame thrower* : A flame thrower may be very satisfactorily used for sterilizing the seed bed soils. It gives a very high temperature (2000 C) and the operations can be done very thoroughly.

II.—Chemical Methods.

Many different chemical agents have been tried either as a drench or in powdered form but only a limited number have ever come into general use.

(i) *Formaldehyde solution*: This fungicide has been used as a drench for the disinfection of seedbeds. The amounts recommended have been one volume of the commercial product to 100 volumes of water applied at the rate of one gallon per square foot. The soil is prepared, the drench applied, the soil then covered with a heavy canvas for 24 to 48 hours and then allowed to air for one week to 10 days before seeding or planting.

(ii) *Formaldehyde dust*: This has been recommended for the control of damping off and other soil fungi according to the following method: Mix 6 ozs of commercial formaldehyde dust with each cubic foot of soil by shoveling it over several times. Place the soil in pots and plant the seeds at once if desired but water as soon as planted. If weak or low vitality seeds are to be used, they should not be planted until 24 hours after the treated soil has been placed in the pots.

(iii) *Copper carbonate dust*: The soil may be watered with a mixture consisting of one 1 oz. of the dust to 6 quarts of water. Sprinkle the soil after planting with this mixture at the rate of one pint to each square foot of surface. The same mixture may be used as soon as signs of damping-off appear after the seedlings are up and applications may be repeated if necessary.

(*iv*) *Mercury compounds*: Effective control of soil infesting fungi has been obtained by (*a*) calomel or mercurous chloride, (*b*) corrosive sublimate or mercuric chloride and (*c*) organic mercury compounds such as *Uspulun*, *Semesan*, *Germisan*, etc.

(*v*) *Kerol*: This has been found very satisfactory in controlling soil fungi. The soil is drenched by a solution containing one part of kerol in 500 parts of water till the soil is saturated.

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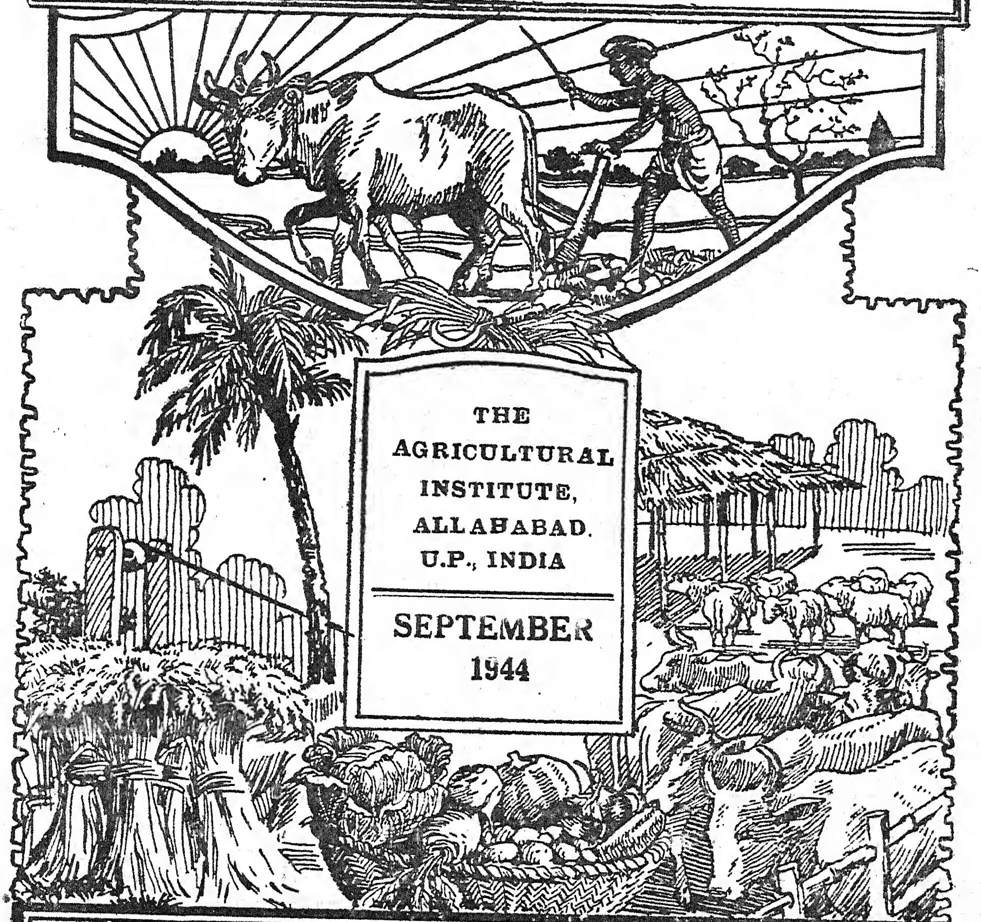

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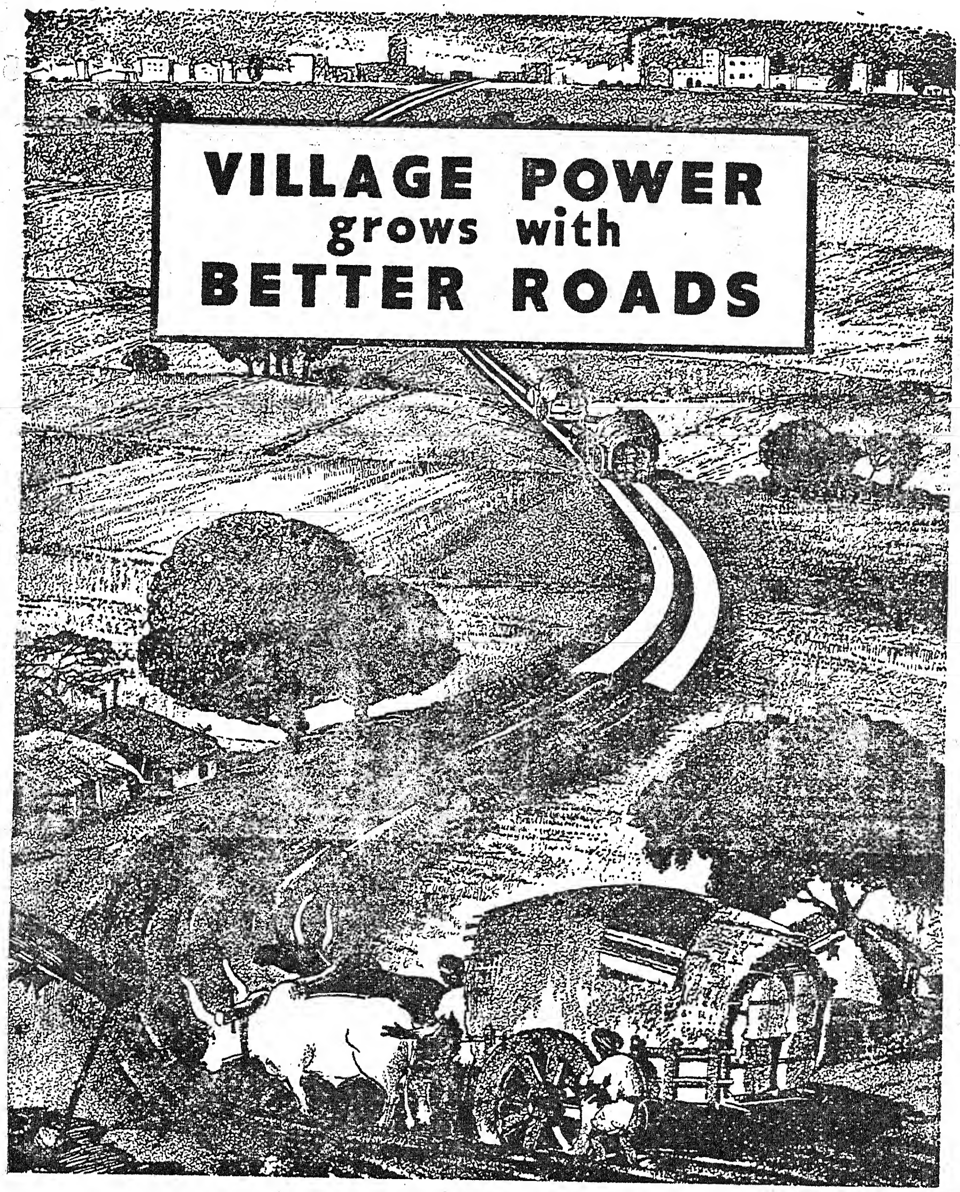

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THE

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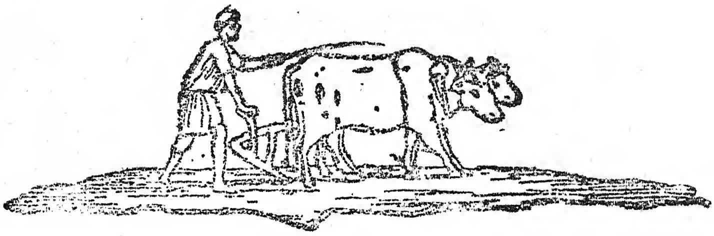

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Editorials

Dr. Sam Higginbottom retires.

This issue of the Allahabad Farmer is again a special issue giving the reports of the activities of the various departments of the Allahabad Agricultural Institute. Two other annual reports appeared before this. But this one is appearing at the time when the Founder and Principal of the Allahabad Agricultural Institute is retiring after having served the Institute these last forty-one years. We, therefore, consider it appropriate to say something at this time of the Founder adn Principal of the Allahabad Agricultural Institute in this special issue which gives the reports of the activities of this institution as they are in a way an indication of his vision and farsightedness and of the great work which he has accomplished in these last forty-one years.

Dr. Sam Higginbottom came to India from America in 1903 as Professor of Economics in The Allahabad Christian College. He soon realized that the remedy for India's hunger and poverty and the solution of her economic problems lies in the development of agriculture. Since then he has planned and founded the Allahabad Agricultural Institute and ceaselessly worked for it. The institution made its humble beginning as the Department of Agriculture of the Allahabad Christian College (now Ewing Christian College) at Allahabad in the year 1910. Two years latter it shifted to its present site on the right bank of the Jumna river just across the bridge from the city of Allahabad. The selection of the site was in itself an experiment as the land was badly eroded and out of cultivation. After thirty-four years of patient work one looks with envy at the rich harvests gathered at the Institute threshing floor. It is one of the largest demonstrations of how scientific agriculture can help to rid India of her poverty. Step by step the Institute has grown and has the proud record of being the first institution of its kind in India in more ways than one.

The Institute is the first private institution in India giving a degree course in Agriculture and allied subjects and the only institution giving a degree course in Agricultural Engineering. Again it took the lead in developing a course in Home Economics for young women in India, which has been recognized by the Board of High School and Intermediate Education of the United Provinces. In

the founding of this course, his life's partner, Mrs. Ethel Cody Higginbottom, has played her conspicuous part. The Institute is the only institution in India besides the Imperial Institute at Bangalore training men for the Indian Dairy Diploma. As no Indian State has an agricultural college of its own, and as also several British Provinces have no agricultural colleges of their own, so the Institute filled a real need for many young men from Indian States and Provinces who were anxious to get agricultural education but were unable to secure admission on account of provincial restrictions. The Allahabad Agricultural Institute has kept its doors open to all. It has attracted students from all corners of India, Burma and Ceylon, and even students from countries outside India such as Iraq, Persia, Malaya, Egypt and the Fiji Islands. People who have visited the Institute, (and these have come from all walks of life including Viceroys and Governors, and public men like Mahatma Gandhi, Pandit Jawahar Lal Nehru and Babu Rajendra Prasad) have been unanimous in saying that it is not only the scholastic achievements of the students which is striking, but their outlook of service and readiness to do things. The growth and development of the Institute has been the unfolding of a dream conceived and brought to fruition by the unceasing labours of Dr. Sam Higginbottom. All has not been smooth sailing for he had to face many disappointments ; but having put his hand to the plough, he never looked back. In the words of Professor Foster of Western Reserve University, Ohio, U. S. A., while presenting him to the President of the University for conferring the honorary degree of Doctor of Laws, "Mr. Higginbottom has consecrated himself to the service of his fellowmen, particularly through education......Instead of preaching a social panacea based on theory he has devoted his life to the exemplification of practical Christianity."

But Dr. Higginbottom's great work has not only been confined to the Institute. He was Honorary Superintendent of the Naini Leper Asylum for over thirty years In this also he was ably supported by his life's consort, Mrs. Ethel Cody Higginbottom, who was so much loved by the inmates of the Asylum and by the untainted children of those lepers, that Mahatma Gandhi while visiting the Institute and the Leper Asylum once jokingly remarked that he was almost getting jealous of Mrs. Higginbottom for the love bestowed upon her by so many children. It has taken much giving on her part to enable her to receive so much affection. Dr. Higginbottom has also during these forty years guided and advised on various rural, agricultural, and economic problems, numerous Indian States and Provincial Governments, notably Gwalior, Jodhpur, Bikaner, Indore and the United Provinces. In short, he may be said to have been more successful than any other man in India in making not only the peoples of India, but the princes and rulers of India, to become rural-minded, and to devote their energies to the improvement of agriculture and to the progress of rural India.

Dr. Sam Higginbottom completes his seventieth year on the coming 27th of October. His retirement is also due on that date. In recognition of his services the Presbyterian Board of Foreign Missions has sponsored a campaign to raise a fund in the United States to help the Institute. While funds in America are being raised for the Institute, it was felt that people in India also should show their appreciation of Dr. and Mrs. Sam Higginbottom and the cause for which they have spent forty-one years in India, by raising a similar amount to strengthen the work of the Allahabad Agricultural Institute. The Board of Directors of Allahabad Christian College have, therefore, instituted a parallel project in India. It is proposed to raise Rs. 5,10,725 to be used for buildings and equipment necessary to expand the Institute to the most economical and efficient size. Today, India needs, more than ever before, men and women trained in agriculture and home crafts ; and this fund will help in training practically double the present number of students.

REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY AND DAIRYING, 1943-44

BY

T. W. MILLEN

Milk and Milk Products [J. N. W.]*

The sales of milk and milk products during the period from April 1943 to March 1944, inclusive are given in Table I. The totals in each case for the previous year are included for comparison. There were increases in the present as compared to the last year in the sales of milk, butter, ghee, ice cream and cheddar cheese; decreases in those of *dahi*, cream cheese and cream, although the quantity of ghee is insignificant in either case. The daily average sales of milk during the year increased about 24 pounds over the previous year.

The sales of milk were highest in September and lowest in June. The latter is to be expected as a consequence of the nature of the market to which milk is supplied. The seasonal demand for our milk is indicated by the month to month variations shown. The fact that the sales of milk vary according to the main holiday seasons is also evident. These seasons are the summer holiday, coming in May and June; the *Dashera* holiday, coming in September and/or October; and the Christmas holiday, coming at the end of December and the beginning of January. No unusual situations occurred this year, as in August of the previous year, which otherwise disturbed milk sales. The difference between the maximum and the minimum monthly sales during the year was about 63 per cent of the minimum.

Butter sales varied from 1,078 pounds, 14 ounces, in July to 3,468 pounds, 6 ounces in January. In this case a major portion of the product is sold outside Allahabad so that the seasonal character of the sales of butter is not so pronounced. The availability of cream during the hot and monsoon seasons is mainly responsible for the lower sales of butter during that time. In the winter months, after November, cream is available in greater quantities so that whatever demand there is for butter at that time can be met. The variation in monthly sales amounted to 221 per cent of the minimum.

TABLE I

Sales of Milk and Milk Products from April, 1943 to March, 1944

(Figures in pounds and ounces)

Month	Milk	Butter	Dahi	Cream Cheese	Cream	Ghee	Ice Cream	Cheddar Cheese	Daily Average for Milk
April ...	20510-8	2196-12	1410-8	81-10	30-2	...	3011-8	103-8	683-11
May ...	14644-0	1362-0	621-0	86-0	8-4	...	4299-8	18-6	472-6
June ...	13092-0	1468-14	254-0	69-0	13-0	...	3676-0	65-6	436-6
July ...	18563-0	1078-14	403-0	80-0	10-10	...	3029-0	205-8	598-13
August ...	20897-0	1468-12	392-0	59-8	9-14	2-12	2326-0	197-8	674-2
September	21388-0	1872-14	329-8	37-4	15-12	...	1873-0	285-14	712-15
October ...	18040-8	2501-8	131-8	95-0	20-2	...	2127-0	457-14	581-15
November	18871-0	2849-0	181-0	86-0	32-10	2-8	1483-0	250-6	629-0
December	16946-0	3199-4	144-8	101-12	31-0	11-8	1053-0	265-4	546-10
January ...	15660-8	3468-6	95-8	68-8	40-2	8-8	1001-0	463-4	505-3
February...	17187-8	2975-11	130-0	98-4	34-2	5-4	919-0	480-12	592-11
March ...	19434-0	3426-6	196-8	96-12	37-0	9-10	1939-0	1093-13	624-14
Total ...	215234-0	27868-5	4289-0	959-10	282-10	40-2	26737-0	3887-7	588-1
Previous year Total ...	206147-8	24871-8	16174-0	989-2	283-7	3-12	15411-0	1995-13	564-13

*This part of this report was written by J. N. Warner.

The sales of *dahi* dropped greatly during this year as compared to previous years; they were only about one-fourth as great this year as last. This resulted largely from the increase in the sale price of *dahi* during the period of this report. Whereas the retail price for this product was three annas a pound at the beginning of the year, it was six annas a pound after the 5th of October, 1943. Sales are ordinarily low, as is true of certain other products, during the summer. In July, as the sales were beginning to increase, the price went up to five annas, having gone to four annas on the 20th of April. The sales immediately declined. They further declined, considerably in this case, after the final increase to six annas a pound early in October. The sales of *dahi* varied from 95 pounds, 8 ounces in January to 1,410 pounds, 8 ounces in April, a variation of 1,377 per cent of the minimum.

The quantity of cream cheese sold was practically the same this year as last. Sales varied from 37 pounds, 4 ounces in September to 101 pounds, 12 ounces in December, a difference of 173 per cent of the smallest monthly sales for the year.

The total cream sales were also practically the same as they were last year. In this case, monthly sales varied from 8 pounds, 4 ounces in May to 40 pounds, 2 ounces in January, a difference of 386 per cent of the minimum sales. The total sales of ghee increased from 3 pounds, 12 ounces last year to 40 pounds, 2 ounces this year. This product is only made, however, from small quantities of unsold butter or as a part of the practical instruction given to students of animal husbandry and dairying in the Institute.

Ice cream sales increased about 73 per cent over the previous year. The highest monthly sales were in May with 4,299 pounds, 8 ounces, while the lowest were in February with 919 pounds. The variation in sales from month to month was 368 per cent of the minimum. Considerably larger quantities of ice cream could have been sold, as there was a demand for it throughout most of the year which could not be met. The quantity manufactured for sale during the period from August through February, particularly through November before the cold weather began, was greatly restricted because of lack of adequate milk to meet all demands. During the summer when milk sales were low because of the season, greater quantities of ice cream were made. In the case of milk and ice cream, that season in which milk is demanded in smaller quantities, principally because many of the customers are away for the summer holiday, is the season during which ice cream consumption greatly increases. The special characteristics of ice cream make it a very pleasant and refreshing food when the weather is hot. These two products, therefore, complement each other very well at that season. This is not true, however, during the monsoon and early winter, for ice cream manufacture at that time must be restricted in order to meet the greater demand for milk.

Cheddar cheese continued to increase in importance as a product of this dairy. Sales were practically twice as high this year as last, being 3887 pounds, 7 ounces and 1995 pounds, 13 ounces respectively. The highest monthly sales this year, as last, occurred in March when 1093 pounds, 13 ounces were sold; the lowest monthly sales during the year occurred in May when only 18 pounds, 6 ounces were sold. Price increases on this product, as on ice cream, during the year did not reduce the quantity sold. The sales of cheddar cheese do not show the total demand for this product; they show only the amount it was possible to handle with the amount of milk available. Restrictions were continuously exercised on the amount of milk utilized for cheddar cheese in order to have as much as possible to meet other demands, particularly that for fluid milk.

Cost of production studies

The study of the cost of producing and distributing milk at the Institute, mentioned in the first of this series of reports published in this journal in January, 1942, has continued. A paper entitled The Cost of Producing Milk and Butter Fat, by D. K. Joshi, N. R. Joshi and James N. Warner, reporting the results of a portion of this study, was published in THE ALLAHABAD FARMER, Vol. XVIII, No. 1-2, 1944. An attempt was made in that paper to show the costs of maintaining one milking animal, of producing 100 pounds of milk and of producing one pound of butter fat at this Institute during the calender year 1942. The Institute herd was divided into several groups of animals of which four were considered for purposes of this part of the study, *viz.*, the Red Sindhi, Jersey-Sindhi, ½ Jersey-Sindhi and Murrah cows. The findings showed that, under conditions studied, the Jersey-Sindhi cows produced the most milk, and did so at the lowest cost for 100 pounds of milk or for one pound of butter fat. The Red Sindhi cows produced milk at a lower cost for 100 pounds than did the Murrah cows, while the Murrah cows produced butter fat at a lower cost for one pound than did the Red Sindhi cows. It is suggested by the authors that, so far as the zebu and the buffalo, which are our indigenous milk cattle, are concerned, the zebu is a more economical producer of quantities or volumes of milk, that is, milk which is to be sold as milk; whereas the buffalo is the more economical producer of butter fat. From an economical point of view, zebus should, conseqnently, be kept where milk is to be sold as fluid milk; the buffalo should be used where the milk is to be used for ghee, butter or to supply the needs of a private family. Nearly 58 per cent of the milk of India is converted into ghee, according to the Report on the Marketing of Milk in India and Burma, issued by the Agricultural Marketing Adviser to the Government of India. The buffalo, it appears, rightly occupies an important place in the dairy industry of this country.

The study is continuing with particular reference to the costs involved in the production of milk products and in the distribution of milk and milk products.

Milking stock

During the year under report 4,28,927.0 pounds of milk were produced by our herd of cows and buffaloes. More than half this amount was sold as fluid milk. The remainder was fed to the calves or made into milk products. The production this year was 14,756.2 pounds more than a year ago and the milking herd contained 3 more animals at the end of the year than it did the year before. Table II shows the distribution of the cows according to breed and Table III gives the performance of the cows according to breed. Our Jersey-Sindhi cross-breds are our best performers at the present time. We are anxious to import a fine pure-bred Jersey bull to enable us to increase the milk yield of our herd.

Our Red Sindhi averaged 2800.24 pounds in 331.7 days which is a little better than the minimum yield required for registration of these cows in the Central Herd Book. Of these 29 animals 25 are registered. Nineteen of the twenty-four Murrah Buffaloes are also registered.

Table IV shows the monthly performance of all the cows in our herd, they have been grouped according to breed.

The female young stock shows a net increase of 37 animals during the year. A smaller number were transferred to milk stock this year than the preceding year and one less calf was born during the year.

The increase in the average age at first calving over that of the previous year was in part due to a period of fodder shortage during the first part of the year. Many of our animals lost considerable in body weight owing to the scarcity of feed.

TABLE II

Milking Stock

The strength of the Institute milking herd during the financial year of 1943-44, ending on March 31st, 1944, was as follows :—

Breed	Number on 1-4-43	Transferred from female young stock	Sold	Died	Number on 1-4-44
Red Sindhi	33	5	1	..	42
⅛ Jersey-Sindhi	3	..	..	..	3
¼ Jersey-Sindhi	26	7	4	1	28
Jersey-Sindhi	18	..	..	1	17
Jersey	3	..	..	..	3
⅛ Holstein-Sindhi	5	5	..	..	10
¼ Holstein-Sindhi	5	1	1	..	5
⅜ Holstein-Sindhi	1	..	..	..	1
⅛ Brown Swiss-Sindhi	2	1	..	..	3
¼ Brown Swiss-Sindhi & ¼ Brown Swiss-Hariana ..	19	..	2	..	17
½ Brown Swiss-Sindhi & ½ Brown Swiss Hariana	7	..	1	..	6
Miscellaneous	17	1	4	..	14
Murrah buffalo	38	2	3	..	37
Total ..	182	22	17	2	185

TABLE III

The following statement shows the performance of those animals which completed their lactations during the year 1943-44.

Breed	Number of lactation completed	Average yields lbs.	Average days in milk	Average days dry preceding	Daily av. during milking period	Overall daily average	Number of first lactation heifers
Red Sindhi .. .	29	2800.24	331.7	123.34	8.44	6.2	..
¼ Jersey-Sindhi	19	3948.2	414.5	49.0	9.5	8.5	8
*½ Jersey-Sindhi	16	4616.7	412.5	62.8	11.2	9.7	..
¼ Holstein-Sindhi.. ..	5	4063 7	404.0	104.0	10.1	8.0	..
⅜ Holstein-Sindhi ..	1	6557.5	670.0	132 0	9.7	8.2	..
⅛ Brown Swiss-Sindhi ..	1.	2028.0	265.0	175.0	7.7	4.6	..
¼ Brown Swiss-Sindhi ..	11	3174.9	378.5	88.0	8.3	6.8	2
½ Brown Swiss-Sindhi & ½ Brown Swiss-Hariana ..	3	4428.5	395.3	122 0	11.2	8.5	..
Miscellaneous	10	2987.7	384.5	455.0	7.7	6.94	3
Murrah buffalo	24	3330.9	395.7	110.0	8.4	6.6	8

* Animals in their first lactation are included in the "overall daily average" but are omitted from the "average days dry preceding lactation."

4·0	6·0	5·0	5·0	5·0	3·0	3·0	3·0	3·0	3·0	3·0	6·0	Monthly average	
1·0	..	1·0	1·0	1·0	4·0	4·0	4·0	4·0	5·0	5·0	4·0	No. of cows	6·9
2·24	5·5	7·9	7·0	4·1	5·0	4·6	3·9	3·8	2·1	4·4	7·7	Over-all daily average	5·0
817·6	682·3	595·2	404·8	343·7	447·3	672·8	564·0	531·1	537·9	476·8	416·7	Total	6490·6
2·0	2·0	2·0	2·0	2·0	3·0	3·0	2·0	2·0	2·0	2·0	2·0	Monthly average	
..	..	..	..	..	..	..	1·0	1·0	1·0	1·0	1·0	No of cows	2·6
13·6	11·0	9·9	6·5	5·5	5·0	7·2	6·1	5·8	5·8	5·5	4·8	Over-all daily average	5·9
173·5	194·9	156·1	179·1	160·4	110·5	52·2	538·9	736·3	708·2	558·7	560·6	Total	4129·4
1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	Monthly average	
..	..	..	..	..	..	..	..	..	..	..	..	No. of cows	1·0
5·8	6·3	5·2	5·8	5·2	3·7	1·7	17·9	23·8	22·9	19·2	18·6	Over-all daily average	11·3
2785·9	2980·2	3199·8	2992·4	2305·0	2650·4	3013·0	2418·7	1908·2	2559·9	3564·3	4641·5	Total	35019·3
12·0	14·0	13·0	12·0	10·0	12·0	11·0	10·0	8·0	10·0	12·0	13·0	Monthly average	
5·0	3·0	4·0	5·0	7·0	2·0	2·0	3·0	5·0	3·0	1·0	1·0	No. of cows	14·8
5·5	5·7	6·3	5·7	4·4	6·3	7·5	6·3	5·0	6·4	9·5	11·5	Over-all daily average	6·5
59·3	151·1	144·1	133·7	92·9	..	295·4	347·1	374·9	166·1	380·0	379·0	Total	2623·6
1·0	1·0	1·0	1·0	1·0	..	1·0	1·0	1·0	1·0	1·0	1·0	Monthly average	
2·0	2·0	2·0	2·0	2·0	3·0	2·0	2·0	2·0	2·0	2·0	2·0	No. of cows	3·0
1·8	2·5	1·6	1·4	1·0	..	3·2	3·9	4·0	1·8	4·4	4·1	Over all daily average	2·4
4579·2	4356·0	3831·7	3720·7	3500·1	3640·4	3925·8	3939·2	4856·1	5104·3	4588·6	4329·9	Total	50372·0
22·0	20·0	19·0	17·0	16·0	18·0	15·0	17·0	17·0	19·0	19·0	20·0	Monthly average	
16·0	18·0	19·0	21·0	22·0	19·0	20·0	19·0	19·0	17·0	17·0	17·0	No. of buffs	37·3
4·3	3·7	3·4	3·8	3·0	3·3	3·6	3·7	4·4	4·6	4·4	3·8	Over-all daily average	3·8
26818·0	28218·6	28407·2	28712·0	29055·3	28396·5	29495·7	27849·6	32041·0	35604·5	40342·7	43613·1	Total	378555·0
111·0	111·0	109·0	102·0	106·0	107·0	99·0	102·0	97·0	112·0	115·0	115·0	Monthly average	
33·0	31·0	32·0	38·0	34·0	32·0	37·0	35·0	42·0	30·0	29·0	32·0	No. of cows	140·9
6·2	6·4	6·7	6·7	6·9	6·8	7·0	6·8	7·6	8·1	9·7	9·6	Over all daily average	7·4
4579·2	4356·0	3831·7	3720·7	3500·1	3640·4	3925·8	3939·2	4856·1	5104·3	4588·6	4329·9	Total	503720
22·0	20·0	19·0	17·0	16·0	18·0	15·0	17·0	17·0	19·0	19·0	20·0	Monthly average	
16·0	18·0	19·0	21·0	22·0	19·0	20·0	19·0	19·0	17·0	17·0	17·0	No. of buffs	37·3
4·3	3·7	3·4	3·8	3·0	3·3	3·6	3·7	4·4	4·6	4·4	3·8	Over-all daily average	3·8

Total Milk Production :—Cows—378555·0
Buffs— 50372·0

Total 428927·0

Table IV—*Showing the monthly performance of all cows in the herd.*

April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March		
4926·5	5239·1	5299·9	5912·0	6824·4	5501·6	6066 3	6617·9	8249·6	8745·5	8817·7	9342·9	Total	81543·4
26·0	25·0	22·0	23·0	24·0	24·0	22·0	26·0	27·0	30 0	30·0	28·0	Monthly average	
12·0	14·0	17·0	16·0	16 0	15·0	17·0	14·0	14·0	11·0	12·0	14·0	No. of cows	38·3
4·6	4·6	4·8	4 9	5·5	5 0	5·0	5·5	6·5	7·0	7·2	7·2	Over-all daily average	5·8
5259·7	4933·8	4306·7	5821·3	6184·6	6614·1	6346·8	5712 2	6298 1	6153·1	7249·5	7976·1	Total	72856 0
16·0	14·0	15·0	14·0	15·0	17·0	16·0	17·0	15·0	16 0	17·0	16·0	Monthly average	
2·0	3·0	2·0	3·0	2·0	.	1·0	..	2·0	1·0	..	1·0	No of cows	17·1
9·7	9 3	8·4	11·0	11·6	13 0	12·0	11·2	12·0	11·6	14·7	14·9	Over-all daily average	11·7
1543·6	1800·1	2332·6	2171·9	2378·4	1643·5	2462·8	2069·3	2511·4	2678 0	2240·8	2465·3	Total	26297·7
5·0	5·0	6·0	6·0	5·0	4·0	5·0	5·0	6·0	6·0	5 0	6·0	Monthly average No. of cows	6·2
2·0	2·0	..	..	1·0	2·0	1·0	1·0	..	..	1·0	..		
7·4	8·5	12·5	11·7	12·8	9·1	13·2	11·5	13·5	14·4	12·9	13·3	Over-all daily average	11·34
1465·2	1353·3	1201·5	1196·0	1017·0	649 5	544·3	297·4	109·5	1655·5	1756·0	1733·3	Total	12978 5
5·0	5·0	5·0	5·0	5·0	3·0	3·0	3·0	1·0	3·0	3·0	4·0	Monthly average	
..	..	..	..	..	2·0	2·0	2·0	3·0	1·0	1·0	1·0	No. of cows	4·7
9 8	8·9	8·0	7·7	6·6	4·32	3·6	2·0	0·7	10·7	12·1	9·0	Over-all daily average	7·1
5860·9	5688·8	5508·4	4721 2	5090·8	5633·5	5582·9	5296·6	6069·0	6484·3	8289 9	7723·7	Total	71952·0
24·0	22·0	23·0	18 0	22·0	22·0	19·0	20·0	20·0	25·0	26 0	23·0	Monthly average	
2·0	3·0	2·0	6·0	1·0	2·0	4·0	4 0	5·0	2·0	2·0	5·0	No. of cows	25·2
7·5	7·2	7·2	6·2	7 1	7·8	7·4	7·4	8·0	7·8	10 2	8·9	Over-all daily average	7·8
3251·6	3991·0	4119·1	3860·8	3862·7	3242·1	2508·9	2347·3	3630·8	4568·9	5256·0	5331·0	Total	45970·2
13·0	14·0	14·0	14·0	15 0	15·0	12·0	11·0	11·0	12·0	12·0	12·0	Monthly average	
6·0	4·0	4·0	4·0	3·0	3·0	5·0	6 0	6·0	5·0	5·0	5·0	No of cows	17·6
5·7	7·2	7·6	6·9	6·9	6·0	4·7	4·6	6·9	8·7	10·7	10·1	Over-all daily average	7·2
238·2	173·9	128·1	6·7	30·0	835·3	948·4	826·6	824·8	834·6	741·4	663·7	Total	6251·7
2·0	2·0	2·0	1·0	1 0	3·0	3·0	3·0	2·0	2·0	2·0	2·0	Monthly average	
4·0	1·0	1·0	2·0	2·0	..	..	..	1·0	1·0	1·0	1·0	No. of cows	3·0
2·6	1·9	1·4	0·2	0·3	9·0	10·2	9·2	8·9	9·2	8·6	7·1	Over-all daily average	5·7
336·0	1030·1	1415·7	1312·1	765·4	1066·3	1001·9	813·6	798·1	512·5	1011·6	2379·3	Total	12442·6

Table V

Female young stock 1943-44

Serial number.	Breed.	Number on 1-4-43	Born during the year	Transferred to milch stock	Died	Number on 1-4-44
1	Red Sindhi	30	10	5	1	34
2	1/16 Jersey-Sindhi ..	2	2	..	..	4
3	1/8 Jersey-Sindhi ..	14	13	..	2	25
4	¼ Jersey-Sindhi	35	9	7	..	37
5	Jersey-Sindhi	..	2	..	..	2
6	5/8 Jersey-Sindhi ..	..	1	..	..	1
7	Jersey	..	1	..	..	1
8	1/16 Holstein-Sindhi ..	2	5	..	..	7
9	1/8 Holstein-Sindhi ..	13	2	5	..	10
10	3/16 Holstein-Sindhi ..	1	..	..	..	1
11	¼ Holstein-Sindhi ..	2	..	1	..	1
12	1/8 Brown Swiss-Sindhi ..	20	2	1	1	20
13	¼ Brown Swiss-Sindhi ¼ Brown Swiss Hariana ..	3	2	..	..	5
14	Miscellaneous	17	6	1	2	20
15	Murrah buffalo	29	12	2	2	27
	Total ..	168	67	22	8	205

Table VI

The average age, weight and height at withers at first calving of 22 heifers transferred to milch stock during the year 1943-44.

(*April* 1943—*March* 1944.)

Breed.	Average age.	Average weight in lbs.	Average height at withers.	Number of animals.
Red Sindhi	3·42 years	640·3 lbs.	45·9"	5
¼ Jersey-Sindhi	3·3 „	629·3 „	45·2"	7
1/8 Holstein-Sindhi	3·08 „	649·0 „	46·2"	5
1/8 Brown Swiss-Sindhi	3·18 „	747·0 „	47·4"	1
¼ Holstein-Sindhi	4·1 „	775·0 „	45·6"	1
Miscellaneous	3·26 „	517·0 „	45·3"	1
Murrah Buffaloes	3·3 „	1042·0 „	49·2"	2

Poultry

Our poultry sales consisted primarily of breeding cocks of the White Leghorn and Rhode Island Red breeds. We also had a ready sale for all hatching eggs we could spare. There seemed to be an increase in interest in poultry keeping.

We are rearing two varieties of ducks. One resembles the Rouen or wild Mallard in colour. It is a fine table bird and lays a large number of white-shelled eggs. We have also built up a flock of White Indian Runner ducks from stock loaned to us.

The U. P. Government gave us a poultry grant beginning on January 1, 1944, which enables us to sell eggs for hatching to the villagers at reduced rates. We are confining our efforts in nearby villages where there are professional poultry raisers. Prizes were awarded at our Farmers' Fair on exhibits by villagers of fowls hatched from eggs supplied by us. This year we held a short course in poultry-keeping and forty-six out of fifty-three taking the course secured certificates.

Bronze turkeys, white guinea-fowl and white geese were added to the poultry stock so that we now have representatives of all the types of poultry kept under domestication in India.

Sheep

We secured a fine grade Corriedale ram toward the end of the year and have put him at the head of our flock of sheep. The wool on our grade Merino ewes is very fine but was not quite as long as we would like. We hope to lenghten the wool without changing its quality by using this ram from a breed that was developed by crossing the Merino on one of the long wooled breeds.

TABLE VII

Sheep Statistics for 1943-44

Sex	April 1, 1943	Born	Sold	Butchered	Died	April 1, 1944
Male ...	20	17	3	2	7	26
Female ...	102	20	..	1	29	92
Total ..	122	37	3	3	36	118

Goats

Our Jumnapari goats seem to have become acclimatized to Allahabad now or we have learned how to handle them better than formerly. This last year they kept very good general health. We are placing our emphasis on the production of young males for distribution in the United Provinces under the Stud Buck Scheme of the province. These bucks are sent out at about 18 months of age for grading up the inferior local goats. We sent out 5 such males during the year. One of our best males was kept with the female herd most of the time and we were able to get more than half the flock in kid again within two months of kidding. This resulted in lowered lactation yields and shortened milking

periods, but we are more concerned in enlarging our herd at present than in producing large quantities of milk. We continued to milk all goats twice daily and all kids were pan-fed, never having seen their mothers nor taken any milk from them directly.

Our goat show at the Farmers' Fair was very popular and many cross-bred Jumnapari goats sired by our Institute bucks were exhibited by villagers. We have been pleased to note that these cross-breds are beginning to replace the indigenous varieties in some nearby villages.

The average lactation for six females that became pregnant a second time within a few days of kidding was 355·6 pound of milk. One goat (03) did not breed the second time and produced 545 pounds in the first ten months of her first lactation. During the months of October through March the goats produced 4063·1 pounds of milk.

TABLE VIII

Goat Statistics for 1943-44.

Sex.	April 1, 1943.	Born.	Sold.	Died.	April 1, 1944.
Male	11	5	5	4	7
Female	19	13	0	11	21
Total ..	30	18	5	15	28

Swine

We continued the grading up of the local swine using our pure bred Middle White Yorkshire boars. This year we produced a number of ¾ Middle Yorkshire boars and gilts which closely resemble the pure-bred in type and rapidity of growth. The cross-bred swine are much superior to the local variety. The flat legs and shoulders of the 'desi' give way to plump hams right down to the hock and well filled shoulders. The F_2 is very similar to the first cross, but gives more variation in colour and nose length. We are selecting our swine for white skin and hair colour so all coloured F_2 animals were slaughtered. We are much encouraged with the results of our efforts at selection of the grade animals and believe we will soon have a pig that is preferable to any other in the country for distribution in the villages of India. It can be used to grade up the village animals or be used to replace them. We have used no foreign female stock and some of the villagers in the nearby area have been improving their pigs with our boars at the same time we have been securing our cross-bred females. A number of village swine were exhibited at our Farmers' Fair and we had an opportunity to compare litter mates as reared in the village and in our pens. We had taken in a few pigs as breeding fees from the exhibitors. We were aware that our method of feeding and our with-holding of service until the gilt was 8 months of age were preferable to the village customs, but it was easily evident that improvement in village animals by breeding alone offers quick returns. The improved stock grows faster, is of better type and fattens better than the 'desi.' It can compete with the village animal for food, but gives a better return. Several men are now ready to discard their 'desi' stock altogether.

Twenty-six hogs and two pigs were butchered during the year. The total weight of these animals was 4,095 pounds alive. The 40 head we started out the year with weighed 1,491 pounds and the 103 animals we had at the end of the year weighed 8,807. Therefore, we produced during the year 11,411 pounds of live pork.

Thirteen litters were farrowed during the year. One hundred pigs in all were born giving an average of 7.7 pigs per litter. There were four litters of ten pigs each born, two of which contained ten pigs at weaning time. The heaviest litters weaned weighed a total of 233½ pounds for ten pigs weaned by sow No. 6 and 220 pounds for nine pigs weaned by sow No. 9. These were the second litter for No. 6 and Third for No. 9. All pigs were weaned at two months of age. Males averaged 21 pounds at weaning, with a variation from 28 to 14 pounds; females averaged 18 pounds with a variation from 25 to 10 pounds. At 180 days the male pigs averaged 98 pounds; maximum 135, minimum 66. The females at 180 days averaged 90 pounds, maximum 115 and minimum 53 pounds.

The United Provinces Government has given us a grant for the construction of pens and slaughtering equipment. We in turn are rearing high grade male pigs to be distributed in the province under the Stud Boar Scheme recently started by the new Department of Animal Husbandry. We are also providing instruction in swine husbandry, butchering and meat curing. We believe no other college or university in the country is offering this work.

TABLE IX

Swine statistics for 1943-44

	Stock 1-4-43	Butchered	Sold	Died	Born	Return of Service	Stock 1-4-44
Male	5	16	1	..	..	..	26
Female	9	10	..	..	..	..	55
Pigs	26	2	1	16	100	9	22
Total ..	40	28	2	16	100	9	103

Artificial Insemination

The majority of the calves born in our herd during the year were the result of artificial insemination. Raj Kumar, Reg. No. 0088, son of our late Sindh Queen, sired 66 test-tube calves, bringing his total number of progeny by artificial insemination to 69. Three other bulls sired 9 calves; this makes a total of 75 test-tube calves during the year. Seven buffalo calves were born by artifical insemination, bringing the total to 8 such calves that we have produced at the Institute. We know of no other test-tube buffalo calves in the whole world.

In Table X and XI the results of natural service and those of artificial insemination can be compared. By natural mating 47 calves resulted from 63 services, giving 74.6% conception by cows (excluding buffaloes). The 75 test-tube calves were the result of 99 inseminations, which means 75·8% conception. A comparison of birth weights and height at withers shows very little difference between the two groups.

We are now sending sperms by bicycle to inseminate cows in the city and short rail trips have also been made for the purpose of inseminating cows at a distance from Allahabad.

Table X

Calves born during the year as a result of Direct Service

Breed of cow		Number of cows	Number of services	Calves produced		Average birth weight in lbs.	Average height in inches at withers
				Male	Female		
Red Sindhi ..	..	16	20	10	6	45·0	25·3
$\frac{1}{4}$ Jersey-Sindhi	..	10	17	4	6	52·2	26·5
$\frac{1}{2}$ Jersey-Sindhi	..	2	3	2	..	44·0	24·1
Jersey ..	..	1	1		1	19·0	18·9
$\frac{1}{8}$ Holstein-Sindhi	..	4	5	1	3	49·0	25·5
$\frac{1}{4}$ Holstein-Sindhi	..	2	2	1	1	55·0	26·2
$\frac{1}{8}$ Brown Swiss-Sindhi	..	1	1	1	..	53·0	27·0
$\frac{1}{4}$ Brown Swiss-Sindhi	..	4	5	3	1	54·3	26·4
$\frac{1}{2}$ Brown Swiss-Sindhi	..	2	3	2	..	58·5	27·1
$\frac{1}{4}$ Guernsey-Sindhi	..	2	2	1	1	51·0	25·5
Miscellaneous ..	..	3	4	1	2	58·1	26·2
Murrah Buffalo	..	13	14	5	8	67·0	26·9
Total	..	60	77	31	29	.	..

Table XI

Calves produced during the year as a result of Artificial Insemination

Breed of cow		Number of cows	Number of insemina-tions	Calves produced		Average birth weight in lbs.	Average height in inches at withers.
				Male	Female		
Red Sindhi ..	..	19	27	9	10	44·3	25·2
$\frac{1}{8}$ Jersey-Sindhi	..	3	3	1	2	43·3	25·2
$\frac{1}{4}$ Jersey-Sindhi	..	12	14	7	5	43·5	24·8
$\frac{1}{2}$ Jersey-Sindhi	..	13	18	7	6	52·7	26·4
$\frac{1}{8}$ Holstein-Sindhi	..	4	5	2	2	52·5	25·4
$\frac{1}{4}$ Holstein-Sindhi	..	3	6	1	2	58·5	26·0
$\frac{3}{8}$ Holstein-Sindhi	..	1	1	1	..	50·0	27·4
$\frac{1}{4}$ Brown Swiss-Sindhi	..	5	5	4	1	57·5	25·9
$\frac{1}{2}$ Brown Swiss-Sindhi	..	3	3	1	2	64·0	26·9
$\frac{1}{4}$ Guernsey-Sindhi	..	1	3	1	..	48·0	24·4
Miscellaneous ..	..	11	14	7	4	50·0	25·7
Murrah Buffaloes	..	7	14*	3	4	67·0	27·0
Total	..	82	113	44	38	..	..

* 7 inseminations for one difficult breeder, 7 for the other 6 buffalo cows.

Bees

We have continued our experimentation with the indigenous bees of India. During the year we had both the hill and plains varieties of Apis indica, Apis florea and Melipona apicolis in our apiary. The wax moth, ant, wasp and bee-eating bird continue to assail our bees. We are continuing our efforts to increase the nectariferous flora of the area and the number of wild bees in the area appears to be increasing.

Blood Meal

For a number of years we have been anxious to secure a more satisfactory source of animal protein than butcher-house offal for our poultry. With the introduction of swine we were again faced with the problem of securing suitable animal protein in quantity. We developed a simple method of utilization of fresh blood in the production of blood meal of high quality. We have been using blood meal mixed with oil cakes as the primary protein supplement for our poultry and hogs. We set up an experiment similar to that used in New Jersey for rearing calves. Cross-bred males to be reared as bullocks were first used for testing the new diet It was found possible to rear a calf to six months of age using blood meal in place of the milk protein from the age of one month. Calculating feed costs and milk at the current rates it was possible to save Rs. 117 on the cost of raising a calf to the age of six months. For each calf reared on the new diet 148 pound of whole milk and 1643 pounds of skim milk were saved for other purposes. More complete results on our work with blood meal will appear from time to time in the "Allahabad Farmer".

REPORT OF THE AGRICULTURAL ENGINEERING DEPARTMENT FOR 1943-44.

By

M. D. Strong

The outstanding event of the year for the Agricultural Engineering Department was the graduation of our first class of Agricultural Engineers. Out of nine men to appear for the examination, seven passed : two in first division, one in third division, and the rest in second division. Mr. M. K. Nandi received a gold medal from the Allahabad University for standing first in applied sciences. The number of applicants for entrance into this year's class was about double the number we could admit, and among these were some of the high ranking students of the U. P. in the Intermediate Agriculture examinations. This emphasizes the growing popularity of the Agricultural Engineering Course.

The staff for 1943-44 in the beginning consisted of Mr. Vaugh, Head of the Agricultural Engineering Department ; Mr. M. Strong ; Mr. G. L. Joneja, B. Sc. in Engineering from Benares Hindu University ; Mr. R. D. Saxena, M. Sc. in Physics and Mathematics from the Allahabad University ; and Mr. Jheti, B. Sc. in Engineering from the Benares Hindu University. Mr. Jheti left early in September and Mr. S. B. Mazamdar, Engineering graduate from Calcutta, completed the school year in his place. Mr. M. K. Nandi and Mr. S. C. Bhatnagar, who were studying in the Agricultural Engineering course, did part-time work in the department. This year we have our full complement of teachers, which includes Mr. Joneja, Mr Saxena, and Mr. Strong, who were teaching last year ; Mr. P. S. Rao, B. Sc. in Engineering from Benares Hindu University, and who has been employed with the Imperial Council of Agricultural Research, New Delhi, for the past two years; M. K. Nandi, B. Sc. Agriculture and B. Sc. Agricultural Engineering from the Institute ; and S. C. Bhatnagar, B. Sc.

Agriculture and B. Sc. Agricultural Engineering from the Institute. We also have two Institute graduates employed in the workshop in connection with the research work. These are Mr. B. D. Sharma, B. Sc. Agricultural Engineering, and Mr. A. K. Bhatnagar, B. Sc. in Agriculture. Mr. Vaugh left early in April for a furlough in America.

This year saw the completion of the first year of research work in connection with the bullock research scheme. Most all of the tests for maximum pull were made using the dynamometer cart and a large variety of single and double yokes. The results of these tests have not been published as yet. The tread mill has not been finished because of the shortage of labour and the difficulty in getting meterials; so testing on that part of the scheme has not been started. A large number of body measurements for the bullocks of the Institute have been made, but the sustained loading tests have not been carried out yet. Therefore, nothing conclusive has been determined. This year also saw the completion of the first year of work with the experimental farm allotted to the Agricultural Engineering Department for developing implements and implement procedures. The first year was spent mainly in getting a basis of crop yields and doing preliminary work in outlining the method to be used in the future for a more systematic study of implement procedures. Not many new implements were developed. Some work was done on the use of sweeps for interculture, and a harvest shear was also made, but it was not completed until near the end of the harvest season and, therefore, proper tests could not be carried out.

During the latter part of the year we received word from the Government that we were to receive a grant of Rs. 30,000 for research on farm implements. Rs. 20,000 of this was in a non-recurring grant, and Rs. 10,000 was to be recurring. This is to be used in developing new implements for the hill areas as well as the plains area. Earlier in the year a grant for Rs. 5,000 was received to be used for the purchase of steel and machinery for the workshop.

There have been a great many difficulties in connection with the manufacture of farm implements, which consist mainly of the securing of raw materials and labour to process the materials which are available. The steel stocks were almost completely depleted in the early part of the year, and although negotiations were begun long before the stocks became depleted, nothing in this line was received until in February, when two very small shipments of defective steel were received. In March we received one wagon load of mild steel cuttings, and in early June a small quantity of old railway springs were obtained. These will be of great help in manufacturing implements, but still do not include certain type of materials that are essential to manufacture many of our implements. Very little work in the line of implement manufacture was carried on during the latter half of the year. Coal also was a very big problem and as yet nothing has been received, although Government has sanctioned the supply of one wagon load.

The total volume of implement sales was considerably under last year's total, and the total price realized from sales was considerably lower than any previous year in the last four years except 1940-41, in spite of the fact that implement prices were considerably higher this year. A larger variety of articles was manufactured. Again this year we had no implement salesman because a suitable man could not be found, and travel by rail was very difficult. Most of the sales came from advertising in the Allahabad Farmer, the distribution of implement catalogs, and as a result of the work of the salesman in previous years.

During the year April 1, 1943 to March 1, 1944, the following implements were sold and delivered by the Institute workshop :

Implement	No. Sold During year	Price Realized Rs	a.	p.
Shabash Plough	409	2,844	13	6
Shabash Cultivator	9	363	12	0
U. P. Ploughs No. 1 & 2	10	670	13	6
Wah Wah Plough Sets	13	251	4	6
Seed Drills	3	745	0	0
6″ Mouldboard Shares	822	873	11	0
Hand Hoes	145	165	11	0
Garden Rakes	12	33	12	0
Loppers	8	104	8	0
Hedge Shears	3	27	0	0
Butter Churns (cap. 25 lb.)	6	600	0	0
Butter Workers (cap. 25 lb.)	8	455	0	0
Butter Scoops I. S. 13	7	10	8	0
Scotch Hands I. S. 14	6	4	0	0
Forks I. S. 5	7	10	8	0
Latrine Borers	1 }	296	12	6
Latrine Borer Heads	3 }			
Ladles	2	3	2	0
Butter Mould I. S. 16	1	1	4	0
Butter Mould I. S. 17	3	6	8	0
Butter Mould I. S. 17 (16 oz.)	1	2	5	0
Butter Mould I. S. 18	4	5	8	0
Nagpuri Yokes without pipe bows	6	48	0	0
Milk Measures (1 lb. cap.)	2	7	8	0
Milk Measures (1 sr. cap.)	2	7	8	0
Harness for Single Bullock P.	3	46	1	0
Butter Churn (100 lb. cap.)	1	180	0	0
Cheese Knives	2 sets	17	8	6
Ice Cream Freezer (cap. 1 gal)	2	135	0	0
Ice Cream Freezer (cap. 5 gal)	7	930	9	0
Total ...		8,916	8	0

Two large orders had to be either cancelled or only partially filled. This list of implements does not include those supplied to the Institute. Many prospective customers had to be discouraged because supply could not be made at the time of order, and the orders had to be registered for delivery at a future date and at an unknown price. In spite of this, at the end of this period there was a large number of orders registered with us, as is shown by the following table:

Orders Recorded for Supply at a Later Date.

Implement.	To Govt.	Private.	Total.
Shabash Cultivators	25	8	33
Hedge Shears	0	3	3
Hand Hoes	0	13	13
U. P. P. No. 1 Complete Set	0	6	6
U. P. P. No. 2 Complete Set	0	11	11
Shabash Ploughs	20	84	104
Seeding Machines	0	1	1
Nagpuri Yokes	1	2	3
Wah Wah Plough Sets	1	15	16
Garden Rakes	1	7	8
Butter Churns (25 lb. cap.)	0	4	4
Butter Workers (25 lb. cap.)	0	2	2
Loppers	0	1	1
Butter Workers (50 lb. cap.)	0	1	1

The labour situation in the workshop has continued to grow worse. The number of men employed as fitters and blacksmiths has decreased about 40 per cent. during the last year, and since the beginning of this year a number of others have left or expired. Taking into consideration the unfavorable conditions and the difficulty of getting materials and holding labour, it can be said that implement sales this year were satisfactory.

The situation regarding building is much the same as that of the workshop. Bricks and cement were obtained with great difficulty, and at the present time work on most buildings is at a complete standstill because a wagon load of cement ordered several months ago has not come. The new rural clinic building was partially completed and occupied on February 12. The ward rooms are still incomplete, but can be finished relatively soon when cement is available. The swine barn was completed and occupied, but the large fattening paddocks are still incomplete. The addition to the feed story is also incomplete and must wait for cement. The work is progressing on remodeling living quarters at the Naini Teachers Training Compound to make more space available for staff. Labour has been a very serious problem here also.

Many inquiries concerning the use and application of improved implements have continued to come in, and all such inquiries are given full attention, because it is the opinion of the Agricultural Engineering Department that this is a vital part of our work.

REPORT OF THE DEPARTMENT OF BIOLOGY, 1943-44.

By

W. K. Wesley.

Besides the regular students, several casual students received training in this department.

Botany:—On the suggestion of Dr. Sri Ranjan, Head of the Department of Botany, Allahabad University, Mr. S. R. Barooah carried out two experiments in plant physiology in co-operation with the Agronomy Department. The first one was to see the effect of different oil cakes on the growth and metabolism of paddy. The experiment was laid out in the field using the randomised block method with four replications. There were five treatments, (control, castor cake, *mahua* cake, *neem* cake and linseed cake).—The variety of paddy on which it was worked out was *bansmati*. A number of observations were taken on the growth of paddy such as height, length of leaf, length of sheath, width of leaf, tillering, number of ears, length of ears, weight of shoot and yield of straw and grain. The observations were taken every month till the time of harvest. The cakes were applied on the transplantation bed at the rate of 60 lbs. of nitrogen per acre. The result of the experiment is very encouraging. The *neem* cake showed the best result, then castor cake, then linseed and lastly *mahua* cake. *Mahua* cake has been found to be as bad as control; which shows, probably, that the nitrogen from *mahua* cake is not available to plants soon after application. The detailed results of this experiment will be published very shortly.

The second experiment was to find out the effect of different doses of boric acid on the growth and metabolism of paddy. It has been reported that boric acid, if applied in a small quantity increases the yield, but in excess, has a toxic effect. It was a field experiment with four replications and five treatments. Boric acid was applied in two doses. The first time, after transplantation the powder was broadcast on the plots, and again after a month boric acid was dissolved in water and applied to the plots. The doses both combined were

2 lbs., 10 lbs., 20 lbs. and 40 lbs. per acre. The growth characters were measured and recorded, and also the yield. The experimental data have been analysed statistically and the results show no significance. This shows that the paddy when grown in that soil does not react to boric acid, although in the University Mr. Barooah has found out that paddy grows better in stronger concentrations of boron, up to 20 parts per million. Detailed results will be published later.

Mr. Barooah has also taken up a research scheme to study the vernalization effect on paddy and certain vegetable crops. He has started with ten varieties of paddy. The scheme is to find out the effect of both low temperature and different photoperiods on the growth and development of paddy and other vegetable crops. The scheme has been financed from the Harward-Yenching Fund.

Plant Pathology :—Last year flowers of jackfruits were found coated with black spores in the Institute variety orchard.

The disease was identified as *Rhizopus* by A. Dayal Chand. It was also found that the flowers attacked were males, whereas female flowers escaped the attack and developed into fruits normally.

The disease was injected into female flowers but failed to grow on them.

It is fortunate that female flowers were not attacked, otherwise there would have been a total failure of jackfruit crop, because all the male flowers were attacked and dropped off.

A few permanent slides were also prepared for the use of the classes.

Entomology :—Seven species of swallow tail butterflies (papilionidae), *viz.*, *Papilio demoleus* L., P. *aristolochiae* F., P. *polytes* L, P. *hector* L., P. *nomeus* L., P. *suthus* L. and *P. pammon* L. have been collected during the last several years and the life histories of the first two have also been observed in nature and studied in the laboratory. Of all these species of Papilionidae the caterpillar of P. *demoleus* L. is the worst leaf-eating pest of citrus plants. Its life history and control have already been published in the Allahabad Farmer, Vol. VIII No. 3, May 1934. It has been found out here that the pest passes the winter mostly in the form of caterpillars. The identification, life history and control of *P. aristolochiae* F. and a brief account of the other butterflies is given below.

P. aristolochiae F. is the pest of cultivated climbing *Aristolochia* as well as the wild variety of *Aristolochia indica*. The butterfly is a moderately large insect with a wing expanse of 3″—4″ and is brownish-black to black in colour, and with white and pink to red markings on the hind wings; the head and the abdomen have black dots and markings.

After mating, the eggs are laid by the female on the lower surface of the leaves of the host plant and less commonly on the stems. They are laid singly, are fairly large in size, and brownish in colour. The usual months for egg laying are August and September, and the eggs hatch in four to six days.

The caterpillars are deep velvety brown with a cream coloured band across the abdomen. They are full fed in about 15 days when they measure about $1\frac{1}{4}''$ in length and 3/10″—2/5″ in width. The full fed caterpillar pupates in a chrysalid resembling a torn leaf. The pupal stage lasts for about 7-8 days. The winter months are usually spent in the pupal stage and the caterpillars that pupate in the month of November emerge as butterflies as late as February.

The cheapest and the best way of control is to hand pick the caterpillars and destory them. Garden lizards, *Calotes versicolour*, should be encouraged to feed on the pest. Butterflies can also be destroyed with hand nets.

Papilio polytes L. has been reported from the various places in the plains of India, Burma and Ceylon. This is a brownish-black to black butterfly with a wing expanse of about 3·5″, and having pale to yellow 6 or 7 marks on the

margins of the forewings and on the hind wings. It is a minor pest of citrus plants here and its caterpillar feeds on the different species of this plant.

The same control of the pest can be followed as advocated in the case of the other two butterflies.

Hector swallow tail butterfly, *Papilio hector* L., has also been collected sometimes. Its life history has not been observed here and the butterfly seems to be visiting this place only occasionally.

Tiger swallow tail butterly, *Papilio nomeus* L., has been seen once or twice only.

P. xuthus L. and *P. pamnon* L. have also been collected from time to time on wing.

A special collection of the insect pests of vegetable crops and the fruit sucking moths is being made for further study.

Eugnamptus sp. was observed for the first time destroying mango leaves when Dr. H. R. Mehra of the Department of Zoology, Allahabad University, gave a number of specimens collected by him on grafted mango plants in March. These weevils were seen digging out small holes mostly on the lower surface of the tender mango leaves on either side of the mid rib and laying eggs in these holes. One egg is laid in each hole; and when from one to about a dozen or more eggs have been laid, the weevil cuts the new leaf which is usually still pink in colour near about the petiole, and the leaf containing the eggs falls down on the ground. Here the life history is further continued. The egg hatches in about two to three days time and the newly hatched grub panetrates inside the epidermis of the leaf and feeds there on the tissue. The larva which is white at first and is full grown in about a week when it is 5.0 mm. long, flattened and dirty green in colour. It gets out of the epidermis now and pupates in the soil. In a week the weevil is formed inside the pupa case which comes out and starts feeding on the mango leaves biting small holes, these beetles were again seen laying eggs in August and September on a number of other mango trees.

Sometimes when these beetles are found in large numbers they may prove as major pests. This species is very closely allied to *Eugnamptus marginatus* P. which has been reported from the various places in India but it differs from it in colour, and in having a collar and a very prominent pronotum, and the distal halves of the elytra being ornamented with dark spots and certain other features. I propose to refer to it as *Eugnamptus mehrai* n. sp. till some more light is thrown on the species.

REPORTS OF OTHER DEPARTMENTS

For lack of space reports of the other departments cannot be printed in this issue. They will appear in the November issue of the *Allahabad Farmer*.

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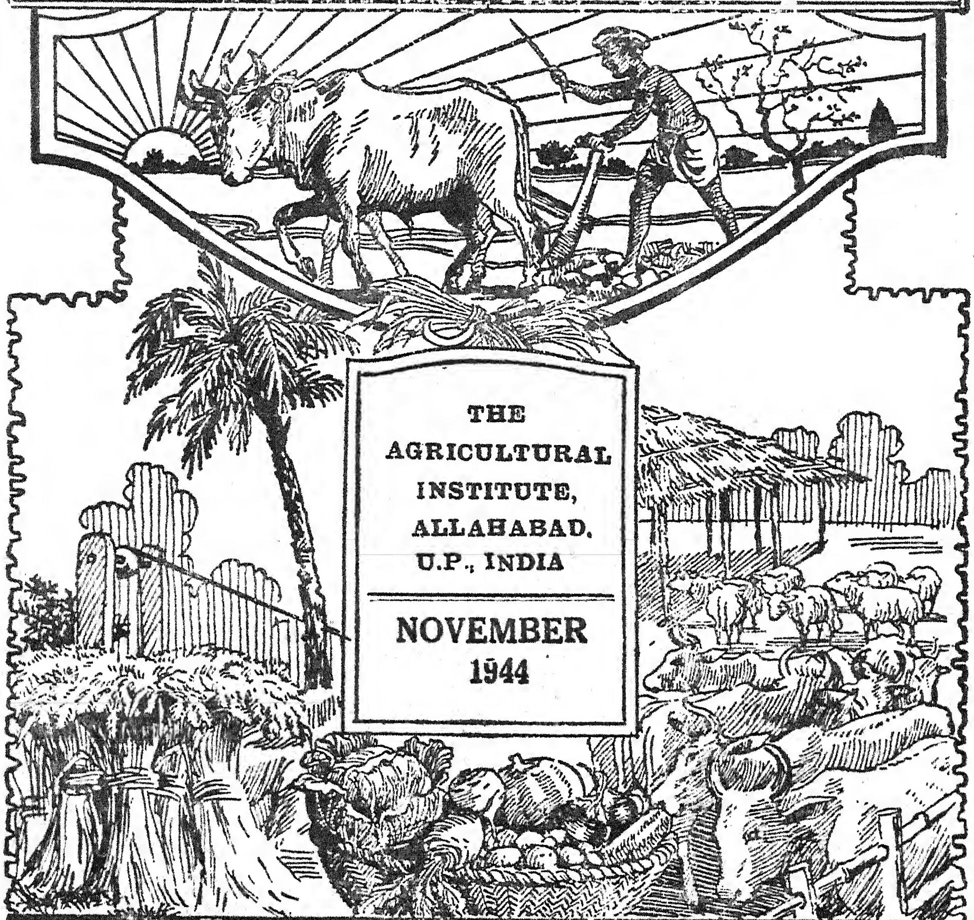

THE
AGRICULTURAL
INSTITUTE,
ALLAHABAD,
U.P., INDIA

NOVEMBER
1944

"On one point, however, there can be but little doubt. The Indian cultivator, though he may be slow in taking up an improvement, will not hesitate to adopt it if he is convinced that it constitutes a better plan, and one to his advantage."

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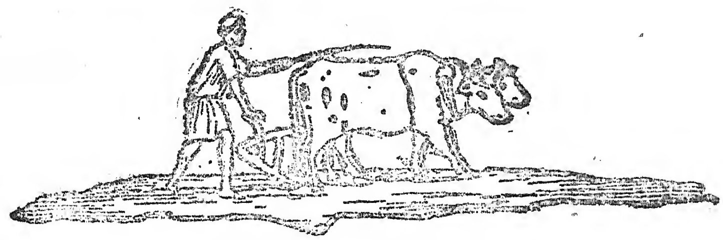

Vol. XVIII] NOVEMBER, 1944 [No. 6

An Editorial

Crop Improvement in India.

The foundation for scientific crop improvement in India may be said to have been laid a great many years ago by such distinguished men as Sir George Watt who put out that monumental work, "The Economic Products of India", Duthie and Fuller, authors of the "Flora of the Gangetic Plain", who thus not only made a study of various crop plants found in this country, but also extended their researches far beyond what is now understood as the field of agriculture, and by Gammie, Jameson, Forbes, Mollison and others. But a great step forward in crop improvement was made by Sir Albert Howard and his talented wife when they made systematic studies of the composition of various crops and then succeeded in making selections of promising varieties or/and evolving new ones: their labours were crowned with a great deal of success. Although they worked in a period when much of the present knowledge of genetics and plant breeding was unknown yet they were able to give to India varieties of wheat which have added crores of rupees to the wealth of the country. Another very outstanding work in crop improvement in this country was that done on sugarcane, the work started by Barber, and later carried on by his successor, Sir T. S. Venkatraman, at Coimbatore. This work also must have added crores of rupees to our national wealth. Other examples of notable success are the evolution of 1027-ALF cotton in the Bombay Presidency, the evolution of C13 wheat and C251 barley in the United Provinces, and the evolution of 8A, 9D, C518 and C591 wheats in the Punjab. These and many other lesser achievements are ones of which plant breeders in this country may well be proud. Results, however, of the last few years appear to have been not commensurate with the knowledge acquired and the new tools now in the hands of the plant breeders. Of course, the phenomenal increase which usually accompanies such work in the early years of selection cannot always be expected. So while we are anxious to see results, we, at the same time, deprecate any undue impatience, as it seems to have often led to a multitude of results which very often appear to be of a doubtful value. We therefore make the following observations for our readers in order to state briefly the problem of crop improvement and to remark in passing as to what attempts are being made to tackle the problem.

First, the plant breeder should be very clear in his mind as to what he is breeding for. For instance, an improvement in one direction may not necessarily be an improvement on the existing varieties if there are other disadvantages which finally offset the ultimate usefulness of the crop to the cultivator or the consumer. For example, a cotton possessing long staple length may be useles unless the variety also possesses other advantages such as high ginning percentage, suitability to the area or conditions in which it is to be cultivated, good fibre strength, and other qualities which may bring the greatest possible profit to the cultivator, and which again are very often the qualities which the market demands. It is perhaps with a view to take care of such a situation that the Indian Central Cotton Committee today contains representatives of trade organizations who are acquainted with the requirements of the cotton trade. Or, take the case of another very important crop, wheat. A variety with a capacity for high yield may not be an improvement if that wheat at the same time takes a longer period to mature, or requires more water for its development, or has an inferior market quality.

We are, therefore, very appreciative of the good work done by the Agricultural Marketing Adviser's office in putting out the Marketing Reports of various crops grown in this country. A Survey of the market requirements of the produce is the first step in crop improvement. Having ascertained what types of crop produce the country needs, the plant breeder is in a position to start planning to produce such types. This is then followed by an investigation as to where the various types for the market are best grown and what countries of the world or parts of this country grow such types.

The plant breeder has first to find out where the place of origin of any particular crop is. This is usually the region where one finds the greatest variability of the crop; and one usually does not miss very many if he goes to places of origin of the crop. After having learnt where this is, the country sends out expeditions to that region for bringing all varieties and types available in the region. The Russians did this for almost all kinds of crops produced in their own country. They sent expeditions to Abyssinia and Eritrea to study and import the *drum* wheats, the wheats from which *suji* (semolina) and other wheat products are made; they sent expeditions to Afghanistan to study and import the common bread wheats of that country; they sent expeditions to South America to study and import potatoes of that region; they sent expeditions to Africa to study and import the types of the *juar* (Sorghum vulgare) of that region; and so on. Our country also has done something of this kind, although not on the scale done by Russia and other countries. We imported Java canes which have been used for the 'nobilization' of our Indian canes; we sent an expedition (one man) to Iran to study and import Iranian cottons which are now being used for the improvement of our Western India cottons; we sent expeditions to Iran and Afghanistan for the study and importation of the wheats of that region; and perhaps the importation and later study of the wheats of Baluchistan by the Howard may also come somewhat under this category. The introduction of potato vsarieties from foreign countries for testing in our plant breeding station in Simla is an attempt to take advantage of the expeditions of other countries to South America, the original home of the potato. But more, we believe, could be done. The 2,400 types of wheat we now have in Delhi may somewhat nearly approach the total number of types which we need for wheat. The 4,000 selections of linseed reported to be now maintained in the Central Provinces may also nearly represent all the types that we need in this country; but there are a host of other crops still to be tackled. The success of Java canes, of Adcock and Virginia tobaccos, of American cottons in the Punjab, and of several introductions from other parts of the world are enough examples to encourage us to go further in this direction.

Another step in crop improvement is the survey of a local crop. We have already stated that the Marketing Reports furnish some data along these lines. We have also mentioned above the botanical surveys of the wheats of India and Baluchistan by the Howards. In fact their surveys were not confined only to the strictly botanical characters of the crop, but were also extended to the agronomical characters. And this they did not only with wheat, but with a great number of crops, and that is why they were so successful. If their researches had been more intensive and if their centres of research had been in the area or areas where there is the most intensive cultivation of that particular crop, instead of at Pusa in Bihar, their success would, in our opinion, have been much greater. Hutchinson at Indore also made use of this survey method with cotton. He not only studied the botanical composition of the cotton crop, in the Malwa plateau, but also took pains to understand the needs of the market. He then devoted his energy to the evolution of new varieties possessing economic values. Malvi 9 cotton is one of the contributions he made during his short stay of three years in this country. The study made by the Agricultural Re-organization committee of the United Provinces, which resulted in the production of crop maps for the province as a part of their report is, in our opinion, very valuable in that it not only makes it clear as to where the crop is most concentrated, but also provides a clue as to where the varying types are likely to be found. It also gives certain indications to the plant breeder as to where a research station for any particular crop ought to be located which is usually the place where there is the greatest intensity of that crop. Thus while the technique of crop improvement may be learnt in Pusa, or New Delhi or in England or America, the actual improvement of the local crop can only be done best in the locality itself. While Pusa in Bihar was able to produce some of the best wheats for the whole of India, the production of the Punjab wheats can best be done in the Punjab itself, and of the United Provinces wheats in the U. P. itself. And while it is difficult to breed sugarcane in the United Provinces because of climate, the best test for the suitability of the Coimbatore canes for the United Provinces, the area of greatest concentration of sugarcane in this country, are those carried out in the United Provinces itself. Following this principle, two areas suggest themselves to us as being suitable for the breeding of rice in the United Provinces: these seem to be the Naini Tal district in the North and the Basti district in the North-east. And while we agree that a potato breeding station be located in Simla for the hill potatoes, should we not have another one with proper storage facilities in Farrukhabad in the United Provinces or in Patna in Bihar for plains potatoes which constitute 92 per cent. of the potato crop of this country. These stations once established, should maintain, as mentioned in the cases of wheat and linseed, all the varieties available for that particular crop.

Having learnt the desirable characters of the various types, the task of the plant breeder is to combine those characters by breeding them into one or more types, according to the requirements of those regions. With the present knowledge of genetics and plant breeding, a new variety could almost be produced to order. As an example, the Americans were successful in combining the excellent grain quality, the excellant standing ability, the resistance to a crown-rust disease, and the resistance to smut, qualities which were found in Bond, a variety of oats, with the qualities for good yield, resistance to stem-rust, and character of a Sativa type, which were found in three other varieties, Anthony, Iogold and Rainbow. It will be an interesting problem for us here in the United Provinces to combine into one or more types some or all of the following desirable characteristics in barley: resistance to lodging, resistance to diseases and pests, non-shattering character, tillering capacity, drought resistance, frost resistance and earliness. We suggest that an expedition be sent to Asia Minor, Palestine, Syria, and Afghanistan where most of the cultivated forms of barleys in the world to-day have come from, as a first step for the improvement of this crop. We have

taken barley as an example but we do not for a moment maintain that this is the only crop which needs attention. The report (1937) on Economic Planning in the United Provinces says this, " We consider that agricultural research work for evolving improved varieties of these (lesser millets) should now be taken up systematically in suitable centres." But our contention is that not only barley and the lesser millets, but all crops should be attended to more systematically and in appropriate centres.

More recently attempts to produce new varieties of crop and horticultural plants have been made by subjecting them to X-ray treatment or to chemicals, such as colchicine, which have the property of being able to effect changes in the chromosomal structure of plants. As far as we know no outstanding results in crop improvement have been achieved by these methods, although they seem to offer great possibilities in the future.

When new types are produced, then comes the period of testing. Regional testing or zonal trials of the improved varieties, very much along the lines now followed for sugarcane in the United Provinces, are essential before a new variety is put out as an improved variety. Without these very careful tests, in which the tools of the statistician are now made use of, the plant breeder may suffer a bad name in the eyes of our intelligent cultivators.

In the end we wish to say how grateful we are for the good work already done by the plant breeders, and for the attempts that are being made now in their search for a superior germ plasm in wheat, cotton, sugarcane, linseed, barley, *juar*, rice, and various other crops, in order to produce superior varieties to those the cultivators have at present. But we also hope that the present food situation in the country has aroused us to the great need for a more vigorous and more thorough-going policy of crop improvement, and that we shall pursue our search for new genes methodically and persistently.

REPORT OF THE AGRONOMY DEPARTMENT, 1943-44.

By

B. M. Pugh,

A. N. Singh and S. R. Misra.

Research and Experimentation (B. M. P. & A. N. S.)

The department continued to carry on its research and experimentation with various crops, the main objective being the selection or evolution of the varieties most suitable for this locality.

Sugarcane.—The work which was started in 1942-43 with sugarcane in co-operation with the United Provinces Department of Agriculture was continued during the year. Out of the 9 varieties, namely, CoS.146, CoS.5, Co.312, Co.393, Co.421, CoS.76, and Co.527 which were selected by us in 1942-43 from the list of improved sugarcane varieties sent to us by the Economic Botanist (sugarcane) of the United Provinces Department of Agriculture, Cos.146 had to be dropped, as its performance was so poor as not to justify its continuation. Later on CoS.5 was also dropped as the yield in 1942-43 was not even sufficient to make it possible to include it in a randomized block experiment. Hence a varietal trial of the remaining 7 varieties was planned. The experiment was a randomized block trial with six replications and a plot size of 15′ by 73′ or approximately, 1/39 acre in which there were 5 rows in each plot. Leaving out two border rows in each plot and 4 feet at the end of each row for border effect, the experimental plot size was reduced to 9′ by 65′ or approximately, 1/74 acre, rather small for good results. But the size of the plots had to be limited according to our facilities. The cane was

also very severely attacked by white ants. The following were the total yields of the various canes, in seers arranged in the order of merit, the lines underneath indicating the group in which there is no significant difference.

Co.331	Co.312	Co.393	Co.421	Co.527	Co.313	CoS.76
2028	1789	1509	1393	1212	1153	1019

Of these varieties, Co.331 possesses by far the hardest rind, and was, perhaps, for that reason, less susceptible to the attack of white ants. It was also the most resistant to lodging. From the observation made this year it would appear that Co.312 might have given a better yield than Co.331 were it not for the white ants which reduced the total number of plants of Co.312 to much less than that of Co.331. As this is a preliminary report of the work on this crop, adjusted yields, that is, average yields as adjusted to the number of plants of each variety, have not been worked out.

The sugarcane plots of 1942-43 were also observed during the year 1943-44 for the ratooning quality of the canes based on the estimation of the vigour of the canes on December 1, 1943. The grades obtained by the various canes, on the average, were as follows (arranged in the order of merit):

Co.312	Co.331	Co.393	Co.527 & CoS.5	Co.313	Co.421	CoS.76	CoS.146
5.00	4.12	3.50	2.33	2.20	1.83	0.83	0.66

It must be remembered, however, that the plots in 1942-43 were even smaller than those in 1943-44 and were not randomized.

PADDY.—A randomised block experiment was laid out in which six varieties of rice were tested. These were Jhalore, Type I, Type 136, Bansi, A.64, and a local variety. Besides testing the varieties, the experiment was also designed to test the effect of putting only one seedling or two seedlings in each hole. In the former case the distance from plant to plant in a row was only 6 inches; in the latter, one foot. The distance between rows was also a foot.

A two-factor randomized block layout was therefore designed in which the smallest unit plot was 8′ by 70′, and there were three replications only. The ultimate plot size after removing border rows from each plot and 2 feet at each end of the plot was only 6′ by 64′. The total yields of each variety were as follows:

Jhalore	Bansi	Local	T.I	T.136	A.64	Significant difference
126.7	96.6	76.6	65.9	60.9	55.7	28.0

the yields of the one and two seedlings respectively were as follows:

1 seedling	2 seedlings	Significant difference
265 45	216.75	36.68

From the above it will be seen that the local varieties, namely Jhalore and Bansi are significantly superior in yield to the "improved" rices, namely T. I, T. 136, and A.64. Even Local, a variety which was obtained locally in the bazaar, was superior, although not significantly. And although the grain quality of the "improved" types is superior to the local varieties, it is questionable, on the results of the above experiment, whether the above "improved" types should be recommended to the cultivators of this area, as the money value obtained by the

cultivator has been estimated to be greater in the case of the local varieties. It will also be seen from the above results that there is an advantage in putting only one seedling in a hole, for the above varieties, and under our conditions, the seed rate being the same, although this involves extra labour.

Besides the above six varieties of rice that were included in the randomized block experiment, a great number of local varieties and those introduced from Travancore and Hyderabad were grown in multiplication plots for observation, and for further trial if they proved to be promising. Of these, Badshah, Jarwan and Lejura proved to be of some promise and will be tried again next year.

GROUNDNUT.—Four varieties were selected for trial. These were A. H. I, A. 12/24, A. H. 34 and A. K. 10; and they were grown in small plots of 10′ by 70′ and with only 3 replications. The average yield per plot of those varieties was as follows (in lbs):

A. H. I.	A. K. 10	A. H. 34	A. 12/24
24.11	18.45	7.18	4.15

This crop was also subject to the attack of white ants as well as porcupines and various other animal pests. But while A. H. I. has proved superior to other varieties it was found to mature later than the others, which is a serious disadvantage where earliness is required.

ARHAR (Cajanus indicus).—Six varieties of this crop were experimented on this year. These were I. P. 80, I. P. 51, Type 136, Rammonia and a local variety. The plot size was 15′ × 72′, and there were 6 replications. The ultimate plot size after leaving out non-experimental portions was only 9′ × 66′. The yield of arhar seed from each variety was as follows (in lbs.):

I. P. 80	Local	Rammonia	I. P. 51	T. 136	Significant difference
212.05	205.65	158.50	141.70	92.05	51.84

Of these I. P. 80 and I. P. 51 are Imperial varieties, Rammonia and Local are local varieties, and T. 136 is an "Improved" U. P. type. Here again, it is very questionable whether T. 136 should be recommended for the Allahabad area. In fact there does not seem to be any advantage in recommending I. P. 80 or I. P. 51.

JUAR (Sorghum vulgare).—Six varieties of *juar* were put in a randomized block trial. These were Do-dana Yellow, Do-dana White, T-9, 5-Tall, 8-B, and Malwa. The first two are local varieties, and the next three are "improved" U. P. juars, and the last was a selection from Central India. The plot size was 12′ × 72′, and there were six replications. The ultimate plot size after leaving out non-experimental portions for border effect was 8′ × 68′. The yields of grain of the several varieties were as follows (in lbs.):

5-Tall	D. D. Yellow	Malwa	D. D. White	8-B	T.9	Significant difference
146.3	138.1	134.7	128.3	124.9	91.6	20.62

From the above results it appears that the varieties 8-B and T-9 cannot be considered as "improvements" on the local *juars*. It is questionable even if 5-Tall can be so considered, as it has not shown any significant difference from Do-dana Yellow or even Do-dana White.

BAJRA (Pennisetum typhoideum).—Five varieties were included in a randomized block trial. These were T. 11, T. 16, Allahabad 4, Allahabad 6, and Local. The first two are Government "improved" varieties, the next two

are local, and the last is a variety selected some years ago from a local crop. The plot size was 12′ × 70′, and there were six replications. The ultimate plot size after leaving out non-experimental portions was 8′ × 66′ only. The yield of grain for each variety was as follows (in lbs.):

Local	T. 16	T. 11	Alld. 4	Alld. 6.	Significant difference
90.45	80.85	71.10	70.30	61.40	16.49

The yield of the fodder for each variety was as follows (in seers):

Alld. 4	Local	Alld. 6	T. 11	T. 16	Significant difference
490.5	434.0	395.0	374.5	371.0	61.23

The results of this experiment also would indicate that of the "improved" variety T. 11 is significantly inferior to Local in the yield of grain, whereas T. 16 is significantly inferior in respect of fodder. Local may be considered the best for this locality even though it is inferior to Alld. 4 in the yield of fodder.

GRAM.—Six varieties were included in a randomized block trial. These were Indore 707, Indore 4, I. P. 58, I. P. 17, and Local. The plot size was 11′ × 48′, and there were six replications. The ultimate plot size after the removal of non-experimental portions in order to remove the border effect was 9′ × 46′. The yield of grain for each variety was as follows (in lbs.):

Local	I. P. 17	I. P. 56	Indore 4.	I. P. 58	Indore 707.	Significant difference
54.60	47.05	44.30	42.05	39.00	27.20	8.62.

Here again it appears that a local variety is better than any of the "improved" varieties, although not significantly superior to I. P. 17. Although I. P. 17 has a better appearance as it has a more uniform grain, still it is questionable whether it should be recommended to the cultivator of this area.

In connection with the above experiment another factor was brought in, and that was to test whether "nipping" the gram plants, a method usually practised in the villages, is advantageous. The results obtained were as follows:

	Yield of grain	Yield of bhusa
Nipped	69.80	444.20
Unnipped	72.85	417.15

These results would indicate that there is no advantage or disadvantage in nipping. That is, there would be no harm to the crop if it is the wish of the cultivator to remove the tender leaves for vegetable purposes.

BARLEY.—Five varieties were tested this year in a randomized block experiment. These were T. 29, I. P. 21, C. 251, Local and 300-A. The size of the plot was 11′ × 48′, and there were six replications. The ultimate size after removing the non-experimental portions was only 9′ × 46′. The yields of grain of the varieties were as follows (in lbs.):

C. 251	I. P. 21	T. 20	Local	300-A	Significant difference.
135.00	108.55	106.35	104.10	99.75	222.36.

The yields of *bhusa* (straw) showed no significant difference and were as follows (in lbs):

T. 20	I. P. 21	300-A	C. 251	Local
240.65	204.95	197.75	194.60	177.40

A full report on the experiments on this crop was made in the Allahabad Farmer, Vol. XVII, No. 4. A summary report of the experiment on this crop in 1942-43 was also made in the report of the Agronomy Department which appeared in the Allahabad Farmer, Vol. XVII, No. 5. The results of the experiment this year (1943-44) as well as last year, seem to bear out the conclusions arrived at in 1941-42 after a series of experiments carried out for several years, and the results of which were reported as stated above in the Allahabad Farmer. These results show that Government "improved" varieties, as far as this crop is concerned are an improvement on the local crop, and may, therefore, be recommended to the farmers of this area. We have used the word "may" in the last sentence advisedly, as we have not made a complete survey of the local varieties of barleys in this area. Until that is made it may not be altogether advisable to displace the local barleys with Government "improved," varieties.

The department of Agronomy also received this year a great number of barleys from the Economic Botanist, U. P. Government, for trial in this area. Of these 35/24 seems promising although not better on the average than C. 251.

WHEAT.—Five varieties were tested in a Latin Square layout. These were F. F. I., A. S. 10, I. P. 4, C. 13, I. P. 13, and I. P. 52. The first was a variety which obtained a prize in a local fair, as judged by the appearance of a bunch of 3 entire plants; the second was a selection from the local crop, and the other 3 are Government standard varieties grown in this area. The size of the plot was 21′ × 27′, but the ultimate size of the plot after removing the non-experimental portions, was 19′ × 25′. There was a rather unusual rain this year which flooded the area for some time. The results of this experiment cannot therefore be considered satisfactory, However, the following were the yields of grain (in lbs.):

I. P. 4	I. P. 52	A. S. 10	C. 13	F. F. 1
61.70	52.35	51.90	47.05	42.55

and the yields of *bhusa* (straw) were as follows (in lbs.):

F. F. 1	I. P. 52	A. S. 10	C. 13	I. P. 4
200.45	187.65	176.35	173.30	155.80

The Agronomy Department also co-operated with the Allahabad University in testing Dr. Shri Ranjan's irradiated wheats, but because the plots were very small because of insufficient seed, and because of the abnormal rainfall referred to above, the results of this experiment also cannot be considered satisfactory.

Also the following wheats were tested in small plots: A. S. 2, A. S. 8, A. S. 1, A. S. 9, Punjab 8-A, the progeny of C. 13 × P. 165, Punjab 9 D, Punjab 409, I. P. 125, Jalalia, C. 46, Punjab 591, 38/10, A. S. 6 and selection 128. Of these the most promising seems to be I. P. 125 and also the progeny obtained from crosses made by our students between C. 13 and I. P. 165.

OATS.—A number of oats varieties were also grown in small plots for observation. Those were C. I. (Crop investigation of the U. S. Department of Agriculture) 3716, C. I. 3730, Selection 1290, I P. Hybrid 1, C I. 3725, I. P. Hybrid 3, C. I. 3531, C. I. 3253, Westene, C. I. 3693, C. I. 2054, Mulga and Selection 1027. Weights of fodder and grain were recorded. From the results btained the following were considered promising. C. I. 3693, C. I. 3531, Selection 1027 and C. I. 3725.

Demonstration (S. R. M.)

Expansion of the farm activities called for more labour than its normal requirement but due to war activities there was considerable shortage of agricultural labour. In addition to the shortage, lack of stability of labour and smaller

output of work per worker were noticeable features. In spite of these facts, we averaged 175 workers per working day, which is a rise of 147 per cent from last years and 170 per cent from the year before last. At the same time this year, their wages cost Rs. 97 per working day, which is a rise of 192 per cent. from last year and 309 per cent. from the year before last. Shortage of bullocks for the farm work was another feature this year. The lack of good bullocks presented great difficulties to us. But permanent improvements of the farm went ahead as far as men and oxen could be spared from routine field operations. This consisted of raising and widening bunds for controlling erosion and for use as farm roads, laying down irrigation bunds, raising land above flood level and levelling.

Between April, 1943 and May, 1944, fourteen wagon loads of factory wool—waste manure were secured. This meant a quantity of 7334 maunds (over 265 tons) of manure at a total cost of Rs. 2,130. This was all applied to the farm land recently brought under the new tube well irrigation under the "grow-more-vegetables" scheme. Also all the manure obtained during the year from over 500 cattle was used on the farm.

Kharif harvests, both fodder and grain, were rather low, and the *rabi* harvest was very poor. The yield of vegetables was also below normal. The farm had to depend very largely on irrigation for the production of fodder rather than on rainy season alone. Out of the total production of 137,400 maunds (one maund = 82.33 lbs) of green fodder and grasses in the year, 54.5 per cent. came from rainy season harvests and the rest came from winter and summer harvests. Also the present-day high prices of food grains called for production of better quality fodders than ever before. The trial and cultivation of new fodder crops have been under way. Seasonal *juar*, Napier grass, and summer *bajra* are the staple fodders; cowpeas, green oats, and berseem are the next in importance. Other introductions are annual white sweet clower, sunflower, sweet potatoes and lucerne. Cowpea is a vigorously growing plant, capable of being grown throughout the year and of being cut more than once in the season. It gives an average yield of about 400 maunds of green fodder on irrigated land. Berseem has not done so well as yet. More will be said about these new fodders in later reports.

REPORT OF THE DEPARTMENT OF HORTICULTURE, 1943-44.

By

W. B. Hayes and A. Dayal Chand.

Financially, the year was the most successful in the history of the Department, largely due to the abnormally high prices of fruit which prevailed in the market. This more than counter-balanced the increase in wages. Another factor was the larger area of papayas, one of the more profitable crops under Allahabad conditions. The crop of about three and a half acres of papayas was sold on the tree for Rs. 6,530, and it is believed that the contractor made a very satisfactory profit. Although the maintenance of the experimental section of the orchards cost about Rs. 2,000 more than the income, the total income of the Department amounted to Rs. 12,824, and the expense to Rs. 4,641.

Perhaps because of the large number of Europeans and Americans in the country, and the absence of imported fruit, the price of grapefruit on the market was very high. Prices as high as twelve annas each were obtained. It has been our policy, however, to keep the price of grapefruit down to a reasonable level, not only to avoid unjustifiable profit, but in order to develop a wider market for the future when production will, undoubtedly, be much greater than it is at present. The Institute sold its grapefruit directly to the consumer at the rate of four annas a pound, plus delivery charges. The fruits weigh

only slightly more than a pound each on the average. Even at this rate, the fruit from 79 bearing trees sold for Rs. 2,435, which comes to more than Rs. 30 per tree. Many of the trees are not yet in full bearing. There are also some non-bearing trees, mainly re-plants where trees were removed because of disease.

The need for a large expansion of the fruit industry in India is obvious. Prices are so high as to limit the consumption of fruit by middle class people, while the poorer majority are able to eat far less fruit than is desirable in the interests of health. An increase in acreage would doubtless reduce the price, but even with the present production per acre, the industry would still be profitable with fruit selling considerably cheaper. With proper horticultural practices, the average yield could be greatly increased without a proportional increase in costs, thus justifying a further decrease in prices.

Disease and insects pests continue to cause damage. There has been no further outbreak of wither-tip, but gummosis continues to affect some of the citrus trees, particularly grapefruit. The disease of guavas caused by a species of *Cephalospora* continues to kill many trees in the neighbourhood and has spread to the Institute orchards. As the means of infection is not known, and no control measures have been suggested, the only way of fighting the disease has been the removal of plants as soon as any sign of the disease is observed. It is not yet apparent whether this will prevent the spread of the disease. The symptoms are the wilting of leaves on part of the tree, and the discolouration of the wood just beneath the bark. In a few weeks from the first wilting, the tree is dead. Reports indicate that the disease is found in various parts of the United Provinces. Mealy bugs appeared in considerable numbers in the spring of 1944 on citrus, custard apple and other trees.

A few additions to the variety orchard have been made, including a number of seedlings of a red-skinned type of guava. Trees bearing such fruit are occasionally found in the district, but as far as we know, no effort has been made to select and propagate this type. The present seedlings should indicate the extent to which the condition is hereditary, and may allow vegetative propagation of the best specimens. The fruit of this type which reaches the market is of very attractive appearance, but generally not of the best quality. The Meyer lemon and two varieties of tangelo set fruit for the first time in 1944. A few of the jackfruit trees planted in 1935 bore a commercial crop for the first time.

A report on the experiment comparing light and heavy pruning of the guava was published in the Indian Journal of Horticulture for December, 1943. On the basis of estimated yields in four years, it appears that the heavily pruned trees planted 15 feet apart produced less than half as much fruit per acre as lightly pruned trees 25 feet apart.

The seedling tree brought from the Kumaun hills and tentatively identified as *Citrus macroptera* var. *combara* has proved very slow-growing. This species seems very much like the *satkora* reported by Nandi, Bhattacharya, and Dutt (1) as a rootstock under trial in Assam, which, like our species, grows into a large and beautiful tree in the hills, but grows very slowly on the plains. They, however, identify this as *C. hystrix*.

In the field of horticultural products, work on the standardization of tomato juice and of mango squash was continued. A satisfactory recipe for onion pickles was worked out.

Mr. K. B. Mathur, who returned to the Department in August, 1943, resigned in June 1944, in order to engage in commercial fruit growing.

(1) Nandi, H. K., Bhattacharya, S. C., and Dutt, S. Nursery Behaviour of Five Indigenous Citrus Rootstock Varieties with Khasi Orange as Scion in Assam. Ind. J. Agr. Sci. 13: 489-93. 1943.

REPORT OF THE CHEMISTRY DEPARTMENT, 1943-44.

By

A. P. Brooks.

Staff:—During the year under report the staff has been as follows:—Mr. A. P. Brooks, head of the department, Messrs. C. O. Das and J. C. Gideon, teachers, and Mr. S. K. Roy, demonstrator. Dr. B. B. Malvea, Principal, Ewing Christian College, has continued to teach B.Sc. classes in theoretical chemistry.

In May 1943 Mr. Brooks was appointed officiating Treasurer of the Agricultural Institute, a post which took most of his time, so that he was able to give only limited attention to the Chemistry Department. Mr. Das and Mr. Gideon took over most of the class and laboratory work and Mr. Roy was appointed as a demonstrator to help them. Mr. Brooks continued in general charge of the Department and taught some classes but most of the day by day supervision was handled by Mr. Das throughout the year.

Equipment and Supplies:—It has become increasingly difficult to secure needed supplies. No new apparatus such as balances, etc., was procured during the year. Replacements of glassware and chemicals was only partial, as only a part of the materials needed could be found on the market. And much of what could be secured was of inferior quality at double or more former costs. However, enough materials were secured to allow the laboratory to continue most of its normal teaching work. In the B.Sc. practical work several exercises had to be discontinued because of shortage of particular equipment or chemicals.

Activities:—As usual, most of the work done by the department is routine teaching, both theory and practical. The starting of Intermediate classes in Home Economics for girls led to a new course in elementary chemistry which the department was called on to teach. Otherwise the teaching load was much the same as before.

From time to time the department has been called upon to help other departments of the Institute in the analysis of substances like feeds, fertilizers, manures, detection of adulteration of milk, etc. For nearly two months the work of anlysis of animal fat was taken up for a local military contractor.

The physician incharge of the Jumna Dispensaries submitted four samples of potassium citrate for analysis, as it was suspected to be impure. On careful analysis none of the samples were found to contain potassium citrate. The attention of the Government officials was called to this, and the dealer was brought to book.

One student from Travancore brought a sample of monazite sand and asked for its analysis with a view to see if it could be used as a phosphate fertilizer. The sample was carefully analyzed and a report given. In addition, other special samples were analyzed from time to time. A complete analysis of a limestone was made and the sample added to the collection of materials used for student practice.

The department co-operated in the annual Farmers' Fair by setting up several exhibits including:—(1) Chemical fertilizers and manures; (2) Methods for detection of adulteration in ghee; (3) Distillation of essential oils; (4) Geological collections; (5) Removal of stains and ink spots; (6) Chemical amusements, and (7) Manufacture of soap.

FARM POWER FOR INDIA.*

By

MASON VAUGH

Agricultural Engineer, Allahabad Agricultural Institute.

In the previous paper, I developed the idea that, while Indian agriculture is generally considered to be under powered, conditions are not suitable for the widespread substitution of mechanical power for animal power. It was also pointed out that conditions did not appear suitable for any widespread supplementing of animal power by mechanical power in the villages and that, in general, experience in western countries had been unfavourable to the use of mixed animal and mechanical power for field work. It was pointed out that there was large scope for the use of mechanical power in reclamation and development work and as stationary units for such work as pumping, grinding of feed and chaffing of fodder, particularly for silage. I also expressed the opinion that the immediate requirement is the better utilisation of the animal power now available.

It will be noticed that this paper refers to the utilisation of existing animal power, rather than to the development of better animal power. The author recognises that there is also scope for the improvement of the cattle; he is strongly in favour of improving the cattle kept, by all means possible. This phase of the subject is left out of the present discussion as being different and more properly part of a long time programme rather than something which can be immediately effective.

Perhaps the subject can best be handled by dividing it into (1) increasing the availability of existing animal power and (2) the more effective use of animal power available. In both these ways the power actually and effectively available can be greatly increased.

According to the 1940 cattle census, there are in British India approximately 2,165,000[1] bulls and bullocks over three years of age and not used for either breeding or work, about 5% of the number now used for work. There are about 238,000 male buffaloes over 3 years of age and not used for work or breeding. In the Indian States, there are 896,000 bulls and bullocks and 63,000 buffaloes over three years of age and not used. While these figures are large, as compared with the total number of work animals, they are not important. The unused males amount to only about 4·7% of the total males or about 6·6% of males above 3 years of age. It is probable that many of these are defective in some way and not suitable for work. It appears, therefore, that there is no large opportunity for bringing into use any important number of males not now utilised.

There is, however, a large reservoir of potential animal power available in India in the female stock. The use of female animals for work is not widespread in India, but it is by no means unknown. The 1940 cattle census records 556,000 female buffaloes and 2,311,000 cows in British India used for work only. In the Indian States, 130,000 female buffaloes and 665,000 cows are recorded as used for work only. This gives a total of 3,692,000 females used for work as compared with 51,686,000 males or about 7·1% as many females as males. These females are listed as used for work only. It is reported (privately, not in the census figures) that in certain districts of the Punjab, female buffaloes are worked even when giving milk. No information is available as to whether female buffaloes or cows are worked while in milk elsewhere in India. Cows are so worked in Europe. Mares are worked while suckling a colt and while pregnant

* Continued from the May, 1944 number of the Allahabad Farmer.

1. All figures have been rounded to the full thousands.

and it is not considered detrimental to them to be given moderately hard work while suckling the colt. Some experiments have shown that even when doing heavy work, mares of some breeds have more milk than the colt can utilise. Mares are considered approximately equal to male horses in Western countries; and the only extensive tests known of the ability of bovine animals to work deals with cows rather than with bullocks. Coolie women continue to work when carrying or nursing a child or even when doing both.

Experiments have recently been started at the Agricultural Institute in using cows for work in the fields. The start was naturally made with animals which were either sterile or had not bred for some time or those giving low yields of milk. The experiment was mainly tried in connection with a newly started experimental farm. It was necessary to change their foood and place of milking several times. They were near the end of the lactation and the variation which occurred in the milk yield was not greater than would be expected from the changes in food. One animal has dropped a normal calf and will be put back to work shortly. Another is in calf and seems to be undergoing a normal pregnancy. The one which has calved worked till about two weeks before calving. The other has been given rest a couple of months before she is due to calve. These cows have worked well and have maintained their condition about as would be expected of bullocks working under similar conditions. One was worked as the team mate of a bullock for some time and proved to be a better worker. The attitude of the plough men working them has changed from slightly antagonistic to pride in the performance of the cows. They have been used for ploughing, harrowing, seeding, interculture of *kharif* crops, carting and general farm work. The animals used weigh about 600 lbs. each and are near the size of small bullocks commonly used in villages around Allahabad. The cows have done approximately the work required or expected of similar size bullocks.

Whenever the possibility of using females is mentioned, the question always arises of whether it will decrease the milk yield or not. No positive answer can be given to this question so far as Indian cows are concerned as yet. It seems likely, however, that the ordinary cows giving little milk will not be affected if feeding is moderately good. From theoretical considerations and from tests elsewhere, particularly in Switzerland, it seems likely that cows can do as much work as is normally taken from the ordinary farmer's bullocks and still be able to eat the food necessary to produce more milk than they normally now produce.

Where only one pair of animals can be kept, there will be definite advantages in keeping a pair of cows instead of a pair of bullocks, provided they can do the required work. Any milk they can give will be that much more than would be available from a pair of bullocks. The calves will have some value. The cows can be maintained on approximately the same feed required for bullocks. If the practice of making silage can be introduced, the amount and quality of feed available from an ordinary holding can be considerably increased. Careful planning to provide fodder and feed can increase the supply. The use of thinnings from the crops, weeds, and grasses from the fields, bunds and roadsides and other material in most cases not marketable will provide roughage for several months of the year. Improving the feeding will certainly increase the work the existing animals can do.

Aside from the more effective work that can be secured from the existing animals by better feeding, the effectiveness of work animals can be definitely increased by the use of better implements. This increased effectiveness is secured in two ways, (a) by enabling the animals to do the work required with less effort, more work with the same effort or some combination of the two, and (b) by the better farm management practies which better implements make possible.

The Indian wooden plough has been rightly condemned as not doing the required kind of work, though work required but not done has not always been rightly assessed. An equally important defect, if not greater, is the small amount of work it enables a man and a pair of bullocks to do in a given time. Because it is ineffective, it requires going over the ground many times to secure the soil condition desired. The large number of operations required limits the area on which such operations can be done in the time available. Improved implements make it possible to do much more work by doing more completely and effectively what is required in a single or in few operations, thus reducing the time required for any particular area and making the cultivation of a larger area possible. In some cases, implements covering a larger area in a given time—as for instance a three or a five tined cultivator—may do similar work and require possibly a similar number of operations, but enable one man and one pair of bullocks to cover a larger area in a given time. In either case, the net result is that one man and a pair of bullocks can do a larger area in a crop season or can do a higher quality of work on the same area. During the year 1943-44, the two pairs of rather small cows referred to above have done the work on an area of 40 acres with the help of improved implements. Partly because of somewhat abnormal conditions, and mainly because a of heavy infestation of kans and kus grasses, they were hardly able to cope with the work at the time of seeding the *rabi* (winter) crop ; but it seems likely that as the abnormal conditions are overcome, they may be able to cultivate the whole area satisfactorily.

Better farm management practices have much the same effect. They should make it possible to do either more or better work, or both. There are better farm management practices which are made possible by better implements, but which are outside the scope of this paper as they do not have to do with directly increasing the effectiveness of the animal power in use.

The best illustration, perhaps, of the kind of practice here referred to is dry weather ploughing (not necessarily *hot* weather ploughing). There is a fairly long period during the latter part of the winter, early spring and summer when work on the farm is slack and when fields are free of crops. It has been found to be both a good farm management practice and a good soil management practice to plough at this time in preparation for the next crop. With the wooden plough this is impossible unless there is rain to soften the soil. With a suitable improved plough, it is possible to do ploughing at this season with small bullocks or cows. This work is, therefore, gotten out of the way, making possible the earlier seeding of the summer crop which in turn leaves more time for interculture and other operations which must necessarily be done during the rains. By following this procedure, it was possible in the summer of 1943 for the two pairs of small cows to seed and care for 30 acres of juar in a season which was moderately unfavorable because of poor distribution of rainfall.

Such improved practices should in general make it possible for one pair of work animals to do the work now commonly done by two pairs or in some cases for a smaller and lighter—and therefore cheaper to buy and to feed—pair to do the work otherwise requiring a larger pair. If one pair can do the work of two, this is equivalent to doubling the power available, without increasing the maintenance and operating cost. Doubling of the power available would give the cultivators ample power for all work.

Such increased power may be applied in various ways. For the farmer who now requires two pairs of bullocks—and there are many such—it makes possible the doing of the work with one pair. This in turn makes available the feed now given to two pairs for the better feeding of one, for the feeding of a milk animal, or for sale. For the farmer now requiring only one pair it means lighter work, fewer days work, or time for more thorough work. In some cases it may make possible the keeping of only one animal instead of a pair, improving the feed and

fodder situation in the same way as for the farmer now having two pairs. Probably, in general such improved conditions can best be utilised by the one pair farmer to give light work to a pair of cows which will utilise the energy not required for work in the production of milk.

To sum up: Mechanical power can be very well used for preliminary reclamation operations on large tracts, preliminary to subdivision into farms. There are areas in India where such work is needed and where such mechanical power should be applied. Mechanical power can very well be utilised for farmstead work such as pumping, grinding, cane crushing and chaff cutting. For effective economical use in the field, most units at present available require larger areas than are now commonly available to a single farmer. Where such larger areas are available to single farmers, the use of tractors may be economical, but it does not seem socially desirable, in a country having the dense population of India, to especially encourage the development of large farms. Utilisation of mechanical power for some operations, leaving others to be done by individual farmers with cattle, involves difficulties in village organisation and layout and it involves the duplication of power. Such combined utilisation of mechanical power and animal power has been showu by farm management studies to be less economical than the use of a single form of power on any one area. It is not essential to introduce mechanical power in order to introduce improved methods. Any job which needs to be done in the course of ordinary farm operations can be done with animal power if suitable implements are used. The use of better implements will make possible better farm management practices which in turn will make the present available animal power, especially if we include cows, ample for the needs of the country. The conclusion, therefore, is that what is needed at present is not a complete overthrow of the village organisation and the complete upset of agricultural practices involved in the adoption of mechanical power, but the development and utilisation of the animal power now available.

MANURES AND MANURING.*

By

SUDHIR CHOWDHURY

Chapter V

HANDLING OF FARM MANURES

The ultimate consideration in a study of farm manures comprises the best methods of economic handling, both as to labour and as to the saving of the constituents carried by the product. The greater the amount of plant food that can be saved in the manure and returned to the land, the less will be the necessity of commercial sources of these elements. Many methods present themselves as being more or less efficacious, but none are absolutely perfect, as losses by fermentation are bound to occur even though leaching is entirely prevented. Methods of handling are usually chosen because of their adaptability to particular circumstanc s, rather than because of the exact amount of valuable constituents that they will conserve.

The statements made concerning the causes and the nature of the changes taking place in manure must have clearly indicated the methods that must be adopted to prevent loss Very briefly we may sum up the whole matter by saying that manure should, if possible, be kept in a water-tight receptacle to prevent loss from drainage; under cover to prevent leaching; compact and moist to prevent too rapid heating; while chemical absorbents may wisely be added to insure against volatilization of ammonia. Manure should be kept compact, more-

* Continued from the May, 1944 Number of the "Allahabad Farmer."

over, in order to prevent a too large formation of nitrates. The principal part of the nitrogen must enter into combination as nitrates before it is available to the plant, but this change goes on more safely in the soil than in the manure heap. There is danger that if it be allowed to go on too largely in the manure heap, a considerable share of them may be destroyed by the denitrifying organisms that live in the lower parts of the heap. The more nearly manure can be kept under conditions similar to those under which green fodders are kept in a silo, the more certainly will its valuable constituents be conserved.

Barn Construction :

Barn construction is important chiefly because of its bearing on the extent to which the fluid part of the excreta is saved. The details of barn construction may of course be almost infinitely varied, but no farmer should lose sight of the fact that loss of urine and leaching of the manure should be prevented. To this end it is necessary first that the platform and the gutter behind the animals shall be water-tight. In some of the best barns, the gutter is sloped to an outlet from which the urine is led into a cistern or tank set to receive it. This plan is infinitely better than to allow the urine to escape, but for many reasons it seems preferable to keep dung and urine together. Neither by itself is a well-balanced manure. Dung is poor both in nitrogen and potash ; the urine contains little phosphoric acid. If the two be kept together, the manure suits the average crop better than either dung or urine alone. Moreover, if the urine be separatad from the dung, especially in the case of horses, the latter becomes too dry. As a rule then it seems best to use bedding in sufficient quantity so that the dung and urine may be handled together. When urine is collected in cistern it can be poured over manure piles.

Care of Manure in the Barns :

Considerable loss to manure occurs in the barn, due to fermentation and leaching. Before the litter can absorb the liquid, it is likely to ferment and to leach away in exceptional amounts. Therefore, the first care is as to bedding which should be chosen for its absorptive properties, its cost and cleanliness. The following table expresses the absorptive capacity of some of the common litters.

Absorptive Power of Litter for Water and Ammonia.

Kinds of material.	Water retained by 1000 lbs. of material after 24 hours.	Ammonia absorb by 100 lbs. of different materials.
	Lbs.	Lbs.
Wheat straw	220	0.17
Oat straw	285	—
Pea straw	280	—
Partially decomposed oak leaves	162	—
Dead leaves	200	—
Needles of coniferous trees	175	—
Peat	600	1.10
Sawdust	435	0.05
Air-dried humous soils	50	0.66
Spent tan	450	—
Mosses and forest leaves	275	—
Dry peat moss	1300	—
Peat moss	—	0.86
Muck	200	—
Sand	25	—

It will be seen that in proportion to the amount of liquid held, air-dried humus soil is a most efficient absorber of ammonia. This is no doubt due in part to a chemical union of the ammonia with organic acids present in the humus, as well as to similar union with zeolites and possibly other complex silicates of the mineral portion of the soil. As absorbents of ammonia peat, peat moss and humous soil take the first rank.

In so far as concerns ability to take up and hold water, peat is superior to all of the other absorbents.

Kind and Amount of Litter to Use :

As must be evident from the statements which have been made concerning the different material ussed as litter, the character and value of manure is largely affected both by the kind and by the quantity employed. The plant-food carried into the manure by the litter is by no means unimportant, and it varies widely with different materials. The following table showing composition of some of the more common materials employed will make this point clear :

Composition of Litter (One ton contains in pounds.)

	Nitrogen	Phosphoric Acid	Potash
Wheat straw	9.6	4.4	16.4
Rye straw	11.2	5.1	18.1
Oat straw	14.4	3.6	23.0
Barley straw	11.4	5.0	23.5
Pea straw	20.8	7.0	19.8
Soybean Straw	14 0	5.0	22.0
Buck wheat straw	13.0	7.1	24.2
Millet Straw	14.0	3.6	34.0
Marsh Hay...	17.2	10.6	54.0
Ferns	00.0	7.4	37.2
Leaves	15.0	3.2	6.0

While most kinds of litter carry plant-food to the manure, and while it might, therefore, seem that the greater the quantity used the more valuable the manure, there are considerations which indicate that too free a use of litter is undesirable. In the first place, a very abundant use of litter will make the manure too dry; but more important, the results of European investigations indicate that the presence in the manure of too large amounts of litter of some kinds, particularly straw, is likely to increase the extent to which nitrates formed in the manure are destroyed and the nitrogen they contain lost in the uncombined form through passing into the air. It is the nitrogen of the

urine which is most likely to be affected. In the rapid fermentation of the urine, nitrates are formed. The solid excreta appear to contain organisms likely to decompose these nitrates, leaving the uncombined nitrogen to escape. This nitrate destroying power of solid excreta is very considerably increased by the addition of straw. The use of some straw or material of similar nature is a practical necessity, but the quantity used should be limited to such amount as is essential to secure the requisite comfort and cleanliness of the animal and to absorb the urine. In general, it can be mentioned that the quantity of litter which should be used is dependent upon the class of the animal and upon the character of the food consumed, since watery foods and those containing a large amount of nitrogen cause an increased flow of urine. To this end it has been recommended that the amount for cattle per day should be 9 lbs., for horses 6.5 lbs., and for sheep 3/5ths lb., stated in another way, the litter should be equal approximately to 1/3rd of the dry matter consumed.

The Degree of Conservation Effected by Litters:

It was found by Muntz and Girard that where the loss of nitrogen from the manure of cows amounted to 59 per cent without the use of litter, its addition reduced the losses to 50 per cent and 44 per cent; where excessive quantities of litter were used, the losses were, nevertheless, 41 per cent. In their study of the relative efficiency of straw and peat moss, in the preservation of horse dung, it was found that the loss of nitrogen, when straw was employed was 58 per cent, whereas with peat moss it was but 44 per cent. Similar experiments with straw in the preservation of sheep manure showed a loss of 50 per cent of the nitrogen whereas by the substitution of a litter of earth the loss was reduced below 26 per cent.

Chemical Absorbents:

It has been mentioned that during the fermentation of the manure, part of its most valuable constituent, nitrogen, is likely to escape into the air in the form of ammonia or ammonium carbonate, both of which are volatile. The proper use of chemical absorbents in the barn may in very large measure prevent this loss and at the same time do much to keep the air of the barn pure and wholesome. All must have noticed the strong smell of ammonia in close barns. This can be prevented by the free use of chemical absorbents. Among the most useful of such materials are, land-plaster, kainit, acid phosphate, super-phosphate plaster and sulphate of magnesia. All of these materials help to prevent the escape of ammonia into the air for the reason that the ammonia enters into combination with the acids of the substances used and thus forms a salt of ammonia which is not volatile.

The Action of Gypsum as an Absorbent:

Gypsum has long been considered one of the most important chemical substances for use in the preservation of animal manures. Its value is based upon its ability to transform the unstable ammonium carbonate into ammonium sulphate, whereby its volatilization is prevented. This reaction is expressed by the following equation:

$$(NH_4)_2CO_3 + CaSO_4 2H_2O -$$
$$(NH_4)_2SO_4 + CaCO_3 + 2H_2O$$

It requires about 400 parts of water to dissolve one part of gypsum although its solubility may be somewhat greater in the liquid manure. In order to be effective, the manure pile must be kept quite moist in order that the solution and transformation and the consequent fixation may take place promptly and efficiently.

Reasons for Using Gypsum in Excess :

Theoretically 10 to 12 lbs. of gypsum should be used per ton of dung, but in actual practice from 100 to 120 lbs. should be employed. The reasons are :—

(1) In consequence of the fact that the reverse reaction to that mentioned above is possible, far more than the theoretical quantity of gypsum must be used in order to insure the fixation of even the chief part of the ammonia.

(2) Furthermore, if the material loses its moisture, some of the ammonia of the ammonium sulphate will be changed again into ammonium carbonate.

(3) Potassium and sodium carbonate are present in the urine which also react with gypsum in the same manner as ammonium carbonate.

(4) Under the most ideal conditions for the storage of manure requiring exclusion of air, conditions are created favourable to certain anaerobic bacteria which may reduce the sulphate to sulphide. This in turn readily reacts with carbonic acid to form calcium carbonate with simultaneous liberation of hydrogen sulphide. In this way, therefore, some of the gypsum is destroyed and its efficiency as a fixer of ammonia is consequently lost.

Gypsum safe to Use :

As a manure preservative gypsum possesses the distinct advantage of being a safe substance to use under the cows, in contrast to most or all of the other materials for many of them are likely to injure the feet of the cattle, unless their use is restricted solely to the gutters, or preferably to the manure as it leaves the barn.

Gypsum compared with other Absorbents :

It was found by Muntz and Girard, in the course of their exp eriments that not only gypsum but sulphate of iron, kainit, superphosphate sand calcium carbonate had but slight efficiency as absorbents of dung, a result upported by the work of Julie and others. More recently, however, Severin in laboratory experiments with unsterilized manure, as well as with sterilized manure subsequently inoculated with either watery extracts of manure or with pure cultures of organisms capable of causing ammoniacal fermentation, found that the addition of 4 per cent gypsum to the manure increased the decomposition 10 to 12 per cent. It did, however, at the same time effect the preservation of the ammoniacal nitrogen which had been produced.

The efficiency of superphosphate as a preservative of manure depends primarily upon the gypsum associated with it. Its effect may be heightened in some cases by the presence of small quantities of sulphuric acid or by the presence of small amounts of free phosphoric acid.

Other substances which have been employed at various times as preservatives of manures are crude sulphate of magnesia, kainit, sulphuric acid, and moss impregnated with dilute sulphuric acid which have been used for the preservation of liquid manure in the cisterns or receptacles in which it is sometimes collected and stored prior to its application to the land. The sulphates and even sulphuric acid are all subject to the same reduction and transformation through the agency of anærobic bacteria as gypsum, on which account they have sometimes proved disappointing.

Soil as a Powerful Absorbent of Ammonia :

In experiments performed by Muntz and Girard it was found that uncovered cow manure suffered a loss of 142 milligrams of ammonia but that under otherwise like conditions when covered with soils to a depth of about three-quarters of an inch the loss was about 10 milligrams. Similarly, the loss of ammonia from uncovered sheep manure amounted to 1,642 milligrams but with a covering of soil like that used with the cow manure the loss was but 128 milligrams.

The retention of ammonia by soil is probably due chiefly to three causes :

(1) The first and least important is its direct absorption and retention by the moisture held on the surface of the soil particles ;

(2) The second is its combination with organic acids arising in the course of the decomposition of vegetable debris.

(3) and the third is its entering into combination with zeolites or similar complex silicates.

The following data from Muntz and Girard show the relative amounts of ammonia absorbed by soil and other substances:

Ammonia Absorbed per Kilogram of Dry Matter.

Materials.	Grams.
Wheat straw	1.70
Pine sawdust	0.46
Mossy peat from Holland	8.63
Powdered peat	11.03
Siliceous earth	0.66
Calcareous earth	1.80
Argillaceous forest soil	2·24
Garden soil	5.38
Peaty soil	6.60

It will be observed that the highest absorptive power is possessed by peat and by soils rich in humus, whereas siliceous soil and sawdust both stand low in the list.

Hauling Manures Directly to the Field :

The manure may be hauled directly to the field as soon as it is produced and then thoroughly incorporated with the surface soil by use of the disc harrow. This system has much to commend it. When the manure is hauled out daily and incorporated with the soil at once, the greatest possible conservation of the nitrogen results. This system saves time and labour and when leaching does occur the soluble portions of the manure are carried directly into the soil.

Storage of Manures :

Very often it is not convenient nor possible, especially in certain parts of the year to haul manure directly to the field. Means of storage must, therefore, be provided. This practice, when proper care is taken in storing the manure is very desirable. During storage the manure ferments and nutritive compounds readily available to plants are formed. This rotted manure can be applied to fields at any time, mixed with the soil and a crop immediately sown ; when fresh manure is applied some time must pass before the crop can be sown. This method is, therefore, recommended but great care should be taken in storing the manure.

The method of storing manure in India, however, is a very primitive one. Cattle dung is ordinarily thrown together in large heaps in some such place wherefrom leaching and drainage can take place very easily and absolutely no

care is taken of the urine. No account is taken of the evanescent nature of it most useful constituents, of the ammonia which passes off into the air, or of its salts of nitrogen, potash and phosphoric acid which are leached out of it by the rains; consequently, only the more stable and insoluble part of the manure ever reaches the cultivators' field.

In any method of proper storage of farm manures attention should be paid to the following points:

(1) Prevention of leaching from manure heaps.

(2) Prevention of overheating of manure heaps.

(3) Attainment of equality of composition.

Prevention of Leaching from Manure Heaps:

There can be no more deplorable sight to the eye of an economical and intelligent farmer than streams of black liquid flowing away either slowly or rapidly from a manure heap. These streams are very rich in the soluble ingredients—the most valuable because the most readily available ingredient—of the manure and are particularly rich in nitrogen and potash. It is a common idea, because these black streams smell strongly of ammonia that nitrogen only is carried away by them, but experimental work has shown that even more potash than nitrogen is lost in this way. In a series of experiments extending over four years at Cockle Park, Northumberlandshire, it was found that whereas 23 per cent of the total potash in the manure under observa tion was lost only 15 per cent of the organic matter and nitrogen combined drained away. Little or no phosphoric acid is lost in this way.

Overheating of Manure Heaps:

Overheating of manure heaps which causes too much loss of plant food materials should always be guarded against. Overheating of manure heaps can be prevented by packing the mass well and by keeping the heap in a moist condition by preventing the escape of liquid or at times by frequent sprinkling with water. Attention to these points ensures a minimum of air entering, and so slows down the processes of oxidation, fermentation and decomposition, avoiding undue loss, although it is an impossibility to prevent it entirely.

Equality of Composition:

As far as possible efforts should be made to have a uniform composition throughout a dung heap and to mix well the dung from different animals, or from animals, living under different conditions. It is a bad practice to have separate heaps or separate dungsteads for the different animals kept on the farm. The best results both in the heap and on the crops will be obtained by a judicious mingling of all. For example, the cold dung of cattle will add moisture to the hot dung of horses and prevent 'fire-fanging'; the concentrated poultry manure spread throughout cattle manure will improve its quality, just as the richer manure from feeding cattle will invigorate and strengthen the poorer quality from young growing animals.

Conservation of Urine:

The two systems of conservation of urine which appear to be most suitable for the agricultural conditions of India are what may be called the *open-drain* and *dry-earth* systems.

The *open drain* system is being tried at some of the Government experiment farms. The cattle shed is provided with a stone floor and a 'V'-shaped gutter, one foot wide and four inches deep. The floor has a gentle slope so as to carry the urine down to the gutter which in turn carries it the whole length of the stalls to a masonry tank or cistern outside the stall. This tank or cistern is provided with a concrete floor to prevent the loss of urine by leaching and drainage. As much litter as is available is made use of. The liquid manure is then pumped into manure piles and mixed, or into a liquid manure cart and distributed directly over the land. This method of conserving manure should meet the approval of the landowners, who cultivate their own fields and who can afford the initial cost of making the stone floor gutter and tank, and cistern or pit.

The *dry-earth* system is the one which is most likely to be adopted by the poor ryots, as it is a simple method which involves no initial expenditure and requires no other bedding than the dry earth used. Like the open drain system it is based on sound scientific principles. Dry earth is spread in the stall to a depth of six inches, and is kept in position by a plank of wood of the same depth, supported by bamboo pegs. The earth absorbs the urine and retains its most valuable ingredients. After three or four weeks the urine earth is conveyed to the manure pile and a fresh supply added to the stalls.

By removing the excreta daily the stalls are kept clean; should the earth get baked the surface is slightly scarified by means of a rake so as to make it pervious to the liquid manure.

Conservation of Dung:

(1) *Piles Outside*: Very often in our country manure is stored outside fully exposed to the weather. When this is the case certain precautions must be taken. In the first place, the pile should be located on level ground far away from any building so that it receives no extra water therefrom in times of storm. The earth under the pile should be slightly dished in order to prevent loss of excess water. If possible the soil of the depression should be puddled, or better, lined with cement.

The sides of the heap should be perpendicular so as to shed water readily. The manure should be kept moist in dry weather in order to decrease aerobic action. Each addition of manure should be packed in place, the fresh on and above the older. This allows the carbon dioxide from the well-rotted dung to pervade the fresher and looser portions, thus quickly establishing the anærobic conditions so essential to economic and favourable fermentation.

(2) *Cement Pit*: A covered cement pit for conserving manure is quite a nice and satisfactory plan. These pits may be of any shape but usually rectangular, with a shed covering. In such a pit leaching is prevented by the covering and by the solid bottom. By keeping the manure carefully spread and well moistened, fermentation may proceed with a minimum loss of nitrogen. The pit should be so located that effluvia from the manure will not find their way into the stable.

(3) *Covered yard*: A covered yard for the reception of manure as it is removed from the barns has been strongly recommended in some quarters. Such a yard must have an impervious bottom. The plan advised is to spread the manure from all the farm animals evenly in the yard into which farm animals are turned for exercise. The roof protects the manure. The trampling of the animals keeps it sufficiently solid to avoid too rapid fermentation. The mixture of the dung of the different farm animals, *e.g.*, cow and horse, is rather favourable to the mechanical condition of the resulting product. There can be no doubt that when litter is abundantly used manure may be very perfectly saved under this system,

but this method of storing manure, it appears, will not prove satisfactory a economical under Indian conditions ; for, this system will make necessary, construction and maintenance of so much roof, and also sufficient amount of la

(4) *Deep Stalls*: The storage of manure in deep stalls, a favourite method England, is similar to the covered barnyard system and has been shown to very economical. The deep stall at the beginning of the season is a water-tig pit of moderate size, in which the animal stands. The manger is movable, bei raised as the amount of manure beneath the animal increases. The manure occasionally levelled and litter is very abundantly used. The elements of va in the manure are very perfectly saved under this system, because the urine all absorbed and the compactness of the manure beneath the animal is such as prevent fermentation and the losses which accompany it. Experiments conduc at the Pennsylvania Experiment station as well as in Europe demonstrate conc sively that the elements of value in manure are more perfectly saved under t system than under any other. The only disadvantage of the method is that does not satisfy the sanitary conditions desirable in the housing of cows and production of milk. This method will not be found suitable and practicable unc Indian conditions.

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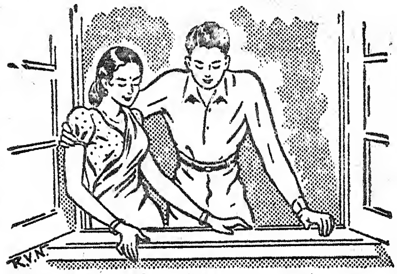
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